BACHELOR BAY AND LANTERN ACRES GAME LANDS AQUATIC INVENTORY

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Introduction

Bachelor Bay Game Land and Lantern Acres Game Land, both state-owned game lands, are located in northeastern North Carolina in the Roanoke and Pasquotank river basins. The Roanoke River Basin originates in northwestern North Carolina and travels through southern Virginia before coming back into North Carolina to drain southeast into the Albemarle Sound. This watershed's 2,414 miles of streams drain portions of 15 North Carolina counties and encompass 3,501 square miles of land. The southeastern portion of this river basin contains one of the most expansive bottomland hardwood forests in the mid-Atlantic region that remains relatively undisturbed. The Pasquotank River Basin consists of a collection of short, wide rivers that drain directly to the Albemarle Sound or to the ocean. The watershed contains only 464 stream miles, but drains 3,635 square miles of 10 North Carolina counties. Most of the water contained in this watershed is from freshwater wetlands and saltwater estuaries. The lower portions of the Roanoke River Basin and the entire Pasquotank River Basin are predominantly blackwater systems and can be highly acidic. Bachelor Bay Game Land is associated with waterways from both river basins, and Lantern Acres Game Land is associated with only the Pasquotank.

Bachelor Bay Game Land consists of 3 parcels totaling 3,620 acres. The largest tract, Huff Island, is located between Middle River and Roanoke River in Bertie County. The smaller tract in Bertie County is located at the mouth of the Roanoke River at the Albemarle Sound (Batchelor Bay), and the other is located several miles to the northeast in Washington County, and drains into the Albemarle Sound via Bull Bay. These and other tracts of land have been in the game lands program since 1977 and have been leased to the North Carolina Wildlife Resources Commission (NCWRC) by Georgia Pacific. Several large tracts (Great, Goodman, and Sunken Marsh Islands, Bertie County) were sold to the U.S. Fish & Wildlife Service in 1991 and became part of the Roanoke River National Wildlife Refuge. In 1995, The Nature Conservancy became the owner of these lands and they continue to lease them to the NCWRC as part of the game lands program. The major waterways associated with Bachelor Bay Game Land are Roanoke, Middle, and Cashie rivers and their tributaries in Bertie County, and Deep Creek in Washington County. The vegetation communities include canopies of primarily bald cypress, water tupelo, swamp tupelo, Carolina water ash, black gum, tupelo gum, and maple with some oaks and sweet gum. The understory is primarily holly, ash, switchcane, and lizardtail. The waterways are either highly acidic, low silt, blackwater streams or neutral, silty, brownwater streams. Soils are primarily acidic, nutrient-poor, wet muck with some areas of silt along the rivers, and soils remain wet most of the year. Prior to acquisition, the area was used for timber, but accessibility limits this as a continued use. Much of the game land is not actively managed, except for boundary posting and fire management, due to wetland regulations. The primary use of this game land is for public recreation (including hunting and fishing), and as a preserve of a unique natural area and bear habitat. Animals hunted include waterfowl, deer, bear, fox, quail, rabbit, squirrel, and raccoon, and sportsmen actively pursue warmwater fishes. Trapping for fur-bearing animals is also permitted.

Lantern Acres Game Land consists of 2 parcels totaling 1,825 acres. The smaller tract is located in Washington County just southeast of Creswell and about 4 miles northeast of Phelps Lake, near the Scuppernong River. The larger tract is located in Tyrrell County in the middle of Hollow Ground Swamp, approximately 10 miles south of Columbia on NC 94. This tract sits west of Alligator River National Wildlife Refuge and north of Mattamuskeet National Wildlife Refuge. The game land was purchased by the NCWRC in 1991 from the Farmers Home Administration, U.S. Department of Administration. The major waterways associated with Lantern Acres Game Land are the Scuppernong River and its tributaries and the wetlands associated with Hollow Ground Swamp. The vegetation communities consist of dry forests, bottomland hardwoods, and pocosins. The soils are highly acidic, poorly drained with a high organic content, and a large portion remains wet year-round. The main use of Lantern Acres Game Land is hunting. Much of the game land is not actively managed, except for boundary posting and fire management, due to wetland regulations. Public hunting on the game land has increased recently due to the opening of a public access road. Most often hunted species include turkey, bear, deer, and small game. NCWRC received funding from the U.S. Fish & Wildlife Service in 1997 to restore and enhance wetlands and to create a small game demonstration site on the game land. The wetland restoration involves planting of approximately 400 acres with water-tolerant native trees, including swamp chestnut oak, water oak, bald cypress, willow oak, and laurel oak and implementing water control structures to maintain wet soils. Dry forest areas are maintained as such. The demonstration site serves as an example of wildlife habitat enhancement for use on local farms.

Land use in the areas surrounding both game lands primarily consists of moderately developed areas, agriculture, or undisturbed natural areas. The area to the southeast of (and presumably around) the game lands was heavily logged in the 1800s and early 1900s. Since then, the natural areas have remained mostly untouched but timber harvest was noticed at numerous locations. The major developed areas in the region include Columbia, Plymouth, Williamston, and Windsor, and factories (Weyerhauser, pork processing, etc.) are common there. Many culturally significant buildings, old homes, and churches exist in the area, particularly in Columbia. The surrounding areas remain mostly rural with agriculture, such as cotton, peanut, and other row crops, and some pasturelands. Surrounding the game lands are several national wildlife refuges that provide habitat for wildlife and preserve rare natural vegetation communities.

The objective of this project was to survey Bachelor Bay Game Land, Lantern Acres Game Land, and surrounding areas for aquatic species, including mussels, sphaeriid clams, snails, crayfishes, and fishes. Our goals were to determine species presence, distribution, relative abundance, and relative health. The inventory included waterways in and associated with both game lands within Bertie, Washington, and Tyrrell counties, North Carolina. Figure 1 and Tables 1a and 1b detail the localities of all the sites surveyed (for both game lands). The following sections provide results of the aquatic inventory for each of the taxa mentioned above. For purposes of this report, *Corbicula fluminea* (Asian clam) was grouped with the sphaeriid clams even though the 2 taxa belong to different families. It also should be noted that any plus or minus symbols listed after road numbers in the following tables represent whether we surveyed downstream or upstream, respectively.

Acknowledgements

We would like to thank the following people, without whose assistance this project would not have been possible: John M. Alderman (NCWRC) for reviewing and editing the report; Dale Davis, Brent Wilson, and others at the Edenton and New Bern depots (NCWRC) for providing information, access points regarding both game lands, and for allowing us to use their motorboats; Dr. John E. Cooper, Dr. Arthur E. Bogan, and Dr. Wayne C. Starnes, Gabriela M. Hogue, Dr. Morgan E. Raley, and Lynn Fullbright from the NC State Museum of Natural Sciences for providing assistance with identifications of crayfishes, mollusks, and fishes, respectively; Dr. Gerald L. Mackie from the University of Guelph, Ontario, Canada, for providing assistance with sphaeriid identifications. We also would like to thank the landowners and residents of Bertie, Washington and Tyrrell counties, North Carolina, who allowed us to work on their property and showed an interest in their local natural history.

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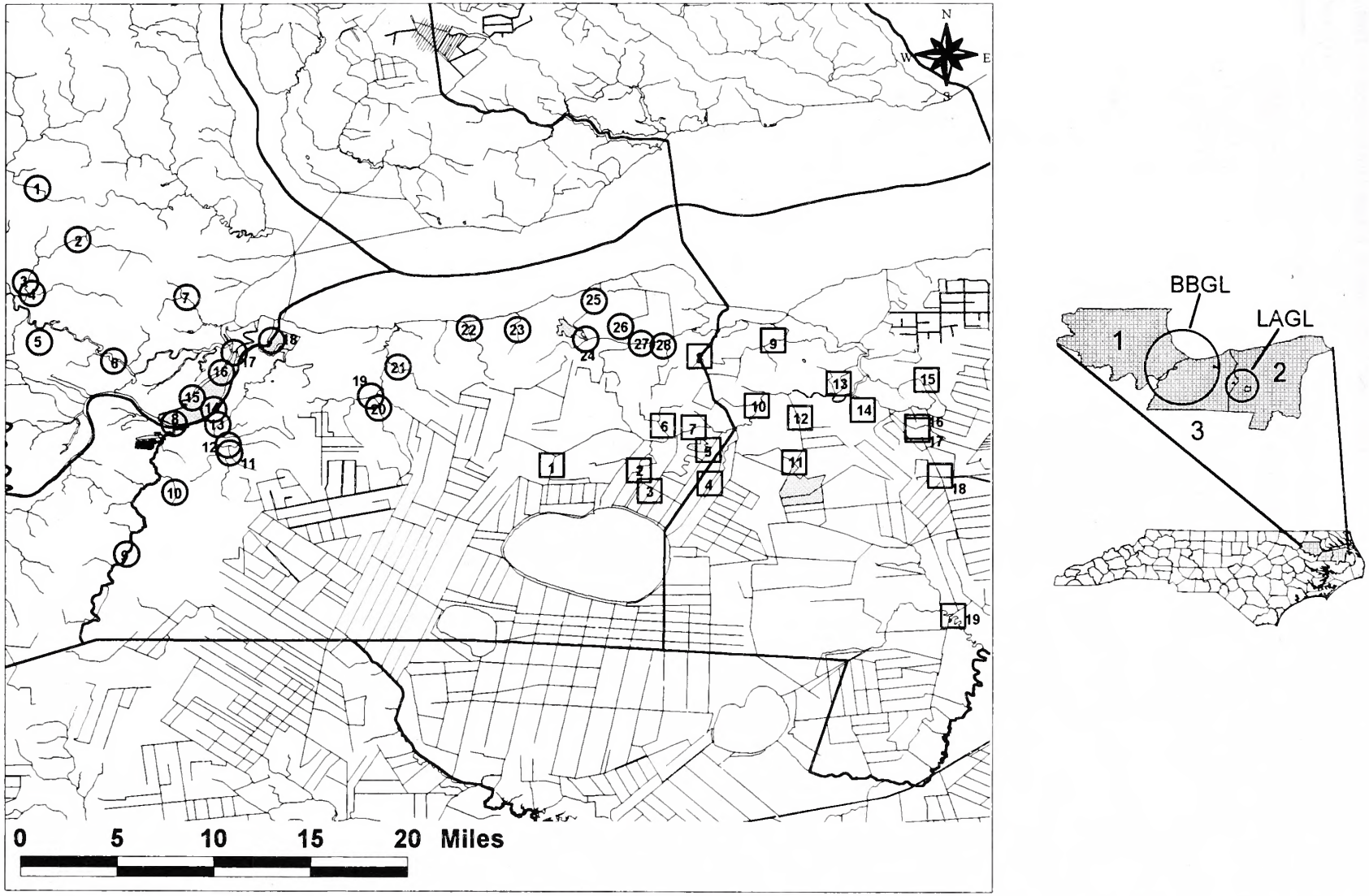

Figure 1. Maps of sites surveyed during the aquatic inventories of Bachelor Bay Game Land (BBGL) and Lantern Acres Game Land (LAGL) in Bertie (1), Tyrrell (2), and Washington (3) counties, North Carolina, 2000. Circles represent BBGL and squares represent LAGL. The location of the game lands within the counties, and the location of the counties within the state of North Carolina, are shown to the right.

Table 1a. Map numbers, the corresponding sites surveyed, and survey effort (person-hours/ electroshock seconds/# of minnow trap nights) for Bachelor Bay Game Land (indicated by the circles on Figure 1).

Map #	Site number	Survey Effort
1	000621.2btw	1.25/327
2	000613.3btw	1.0/296
3	000614.4btw	1.0
4	000614.5btw	1.5
5	000615.2btw	1.5/228
6	000614.6btw	0.75
7	000613.1btw	1.25
8	000809.4btw	1.25
9	000808.1btw	1.25
10	000808.2btw	1.25
11	000621.4btw	incidental
12	000621.3btw	1.75/241
13	000808.3btw	2.0/360
14	000809.5btw	1.0
15	000809.3btw	1.0
16	000809.2btw	1.75
17	000809.1btw	1.5
18	000809.6btw	1.25
19	000808.4btw	1.5
20	000817.3btw	1.25
21	000817.2btw	0.75
22	000817.1btw	1.5/250
23	000622.6btw	1.75/294
24	000622.1btw	1.0
25	000622.5btw	1.0
26	000622.4btw	1.25
27	000622.3btw	1.5/329/3
28	000622.2btw	1.25

Table 1b. Map numbers, the corresponding sites surveyed, and survey effort (person-hours/ electroshock seconds/# of minnow trap nights) for Lantern Acres Game Land (indicated by the squares on Figure 1).

Map #	Site number	Survey Effort
1	000718.4btw	1.1
2	000718.3btw	1.0/224/2
3	000718.2btw	0.75/250
4	000719.2btw	1.0
5	000719.1btw	0.8
6	000718.1btw	1.0/165/1
7	000719.3btw	1.25
8	000719.4btw	0.5
9	000719.5btw	1.5/215
10	000720.7btw	0.5
11	000719.7btw	1.0
12	000720.6btw	1.5
13	000719.6btw	0.4
14	000719.8btw	0.4
15	000720.5btw	0.3
16	000720.4btw	0.3
17	000720.3btw	0.5/177
18	000720.2btw	1.0
19	000720.1btw	1.0

FRESHWATER MUSSELS AND SPHAERIID CLAMS

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Introduction

The freshwater mussel fauna (Bivalvia: Unionoidea), also referred to as unionids or pearly mussels, is an intriguing, diverse, and important group of mollusks. Unionids are often prominent in macrobenthic aquatic communities where, for the most part, they are sedentary filter-feeders. Because unionids consume a major portion of the suspended particulate matter, they provide a number of important roles in aquatic ecosystems, two of which include serving as biological filters and water quality indicators. Mussels also serve as an important dietary component to a number of animals, and economically, their shells provide the nuclei used in the profitable cultured pearl industry (Theil and Fritz 1993). While not as much information has been ascertained for the sphaeriid clams (Bivalvia: Sphaeriidae), also called pea, pill, nut, or fingernail clams, they too serve an important role in aquatic ecosystems as filter-feeders. As part of the inventory of aquatic animals associated with the state-owned Bachelor Bay Game Land and Lantern Acres Game Land, we conducted field surveys of freshwater mussels and sphaeriid clams found in waterways occurring in and around the game lands to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

The life cycle of freshwater mussels is an intricate process that is fairly unique when compared to that of other organisms. Spawning begins with the release of sperm from the excurrent aperture of mature males. As the sperm passively drift with the currents, they enter females through their incurrent aperture. Within sexually mature females, fertilization takes place in the suprabranchial cavity, and the resulting embryos are retained in the marsupial gills until they develop into parasitic larvae called glochidia. Glochidia are obligate parasites and must attach to suitable host fishes. Ortmann (1911) described 2 general reproductive modes for unionids based on the length of time that glochidia are retained in the gills of the female. Bradytictic, or long-term brooders, typically spawn in late summer, brood young over the winter, and release mature glochidia during the following spring or early summer. Tachytictic, or short-term brooders, typically spawn in the spring and release mature glochidia sometime during that summer.

Once maturity is reached, the glochidia are released into the water column through the female's excurrent aperture, from specialized gill pores, or by rupture of the ventral portion of the gill (McMahon 1991). Once released by the female, glochidia passively drift with the currents until they attach to suitable host fishes or die. Mechanisms promoting glochidia-fish contact include respiratory, feeding, and spawning activities of fishes, as well as specialized morphologies and behaviors of particular mussel species (Kraemer 1970, Dartnall and Walkey 1979, Zale and Neves 1982). Attachment occurs on the gills, fins, or scales, depending on the mussel subfamily, and is followed by encystment and metamorphosis into juveniles. Metamorphosis generally occurs over a period of 1-3 weeks (Neves 1991) but can last for a few months (Zale and Neves

1982). Once metamorphosis is complete, the juvenile mussel drops from the host fish, settles into the surrounding substrata, and, if conditions are suitable, grows until sexual maturity occurs. Then, the reproductive cycle is repeated. During a mussel's reproductive years, growth rates are reduced, since significant energy and nutrients are required to produce young.

Unlike unionids, sphaeriid clams are ovoviviparous, self-fertilizing hermaphrodites. All species brood developing embryos in specialized chambers where maternal nutrients are supplied to the embryos. After maturity is reached, the once developing embryos are released into the water column as miniature adults. Due to their relatively large size as mature embryos, compared with other freshwater bivalves (Mackie 1984), most juvenile sphaeriids disperse between drainage systems by clamping their shells onto things such as aquatic insects (McMahon 1991), feathers of waterfowl (Burky 1983), or the limbs of salamanders (Davis and Gilhen 1982) rather than dispersal by water currents. Given highly variable reproductive success rates, sphaeriids typically have 1-3 reproductive efforts per year (McMahon 1991). *Corbicula fluminea* reproduces in much the same manner as sphaeriid clams but tends to use the water currents as its primary means of dispersal (Williams and McMahon 1986). Most populations of the Asian clam have 2 reproductive efforts per year, one in the spring and the second in the late summer (McMahon 1983a).

Habitat Requirements

Freshwater mussels occur in a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with unionids generally being most successful and prevalent in stable, coarse sand, or sand-gravel mixtures (Way et al. 1990a). Water velocity also plays a critical role in the distribution, diversity, and abundance of mussel populations. Unionids tend to thrive in conditions where water velocities are low enough to allow for substrata stability, but high enough to prevent excessive siltation (Way et al. 1990a). Water velocity also affects the amount of nutrients carried to the filter-feeding organisms. Chemical parameters such as pH and calcium concentrations can influence the distributions of mussel populations as well. The majority of species prefer alkaline water with a pH above 7.0, but unionids can grow and reproduce over a pH range of 5.6 - 8.3 and can tolerate acidic conditions as low as 4.7 (Okland and Kuiper 1982). Typically, habitats of low pH also have low calcium concentrations. Low calcium concentrations can lead to poor growth and shell dissolution in some individuals, especially if the shell is worn (Kat 1982). Given that growth and dissolution rates are affected by many factors other than pH and calcium concentrations, the minimum tolerable values can vary significantly among habitats. Another important factor to mention in the viability of freshwater mussel populations is the need for suitable host fishes. If the proper host fish is not present for a particular mussel species at any given location, then eventually this species will become extirpated from the site regardless of the habitat conditions.

Sphaeriid clams and Asian clams are generally more tolerant than unionids of what we consider to be harsh conditions. Unlike many unionids, the diversity and abundance of some *Pisidium* and *Sphaerium* species are inversely correlated with substrata size (Kilgour and Mackie 1988), which may be associated with sediment organic feeding mechanisms. *Corbicula fluminea* has a much broader substrata range, and has been seen to successfully colonize habitat consisting of bare rock outcrops to habitat with high silt loads. The highest abundances of *C. fluminea* in

North Carolina are often associated with sandy, disturbed habitats or with lotic habitats below dams (J.M. Alderman, NC Wildlife Resources Commission, pers. comm.). Sphaeriids have the ability to colonize ponds and lakes where the depth is greater, the flow is negligible, and the sediment and organic loads are high. Again, this may be associated with feeding mechanisms in sphaeriid clams. Chemical parameters such as pH and calcium concentration regulate sphaeriid clams and *C. fluminea* populations in much the same manner that they affect unionid populations.

Taxonomy, Distributions, and Statuses

Freshwater mussels are represented worldwide, with North America containing the largest collection - 297 currently recognized species and subspecies (Williams et al. 1993). While unionids are distributed across the entire continent, the greatest diversity lies within the southeastern United States (Neves et al. 1997). North Carolina's share of this diversity is impressive. Once our taxonomic understanding is more complete, approximately 70 species are expected to occur in our state. A significant amount of literature describing site locations for unionids across North America has led to a more refined understanding of the distribution and taxonomy of this fauna.

Of the 297 recognized taxa of freshwater mussels in North America, Williams et al. (1993) recommended that 213 (72%) be considered endangered, threatened, or of special concern. Nearly half of North Carolina's freshwater mussel species are state listed as endangered, threatened, or special concern, and approximately 30% have undetermined statuses (J.M. Alderman, NCWRC, pers. comm.).

Sphaeriid clams are widely distributed and are represented in North America by approximately 38 species (Burch 1975, Turgeon et al. 1998). In North Carolina, there are approximately 13 species (Adams 1990). No species is currently listed at this time.

Anthropogenic effects, such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration are negatively affecting these taxa. With the introduction of exotic species, such as *C. fluminea*, and the impending introduction of *Dreissena polymorpha* (zebra mussel), the situation continues to worsen. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The freshwater mussel and sphaeriid clam survey of Bachelor Bay Game Land and Lantern Acres Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points, and the Roanoke and Middle rivers were surveyed via motorboat. Since most waterways were swamps, canals, or ditches, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Freshwater mussels were surveyed using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). In areas where water clarity allowed, freshwater mussels were surveyed by viewing the substrata through the water surface with the naked eye. These areas also were surveyed with a view scope depending on the depth of the water. In areas that were turbid or tannic, freshwater mussels were collected by tactilely surveying suitable habitat. Freshwater mussels also were surveyed at sites by sieving the substrata through a dip net or raking the substrata. Tactile, dip net, and rake searches were the dominant survey techniques utilized due to the conditions of the waterways associated with the game lands. If a mussel was located, we typically performed a tactile timed search in the area to determine an approximate abundance at each site. We also noted the type of substrata in which mussel populations colonized to determine if there were any species-specific preferences. Live mussels were identified to species, measured to the nearest mm for length using a Vernier caliper, and returned unharmed to the appropriate habitat. Some individuals were preserved in 95% ethanol and kept for curation. Shells were collected and identified to species, measured for length (mm), and kept for curation. John Alderman (NCWRC) verified some of the species identifications. Brackish water bivalves also were collected in much the same manner, and were identified according to Gosner (1978) and Porter and Houser (1997). All common and scientific nomenclature follows Turgeon et al. (1998) and Johnson (1970).

Sphaeriid clams were collected using a variety of methods, including dip netting and tactile searches. The most prevalent method used was dip netting. This involved running a 1/8-inch mesh dip net through vegetation and the substrata to search for the clams. Most specimens collected were preserved in 70% ethanol and identified according to Burch (1975). Specimens also were sent to Dr. Gerald L. Mackie, University of Guelph, Ontario, Canada, for identification confirmation. All common and scientific nomenclature follows Turgeon et al. (1998).

For each taxon, a survey effectiveness score (SES) was determined at each site (if possible) and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Bachelor Bay Game Land

Over 8 days from 13 June to 17 August 2000, 27 sites were inventoried (site 11 was not surveyed for unionids), and freshwater mussels were collected or observed at 11 sites (Figure 2a and Table 2a). Eight species were collected during the inventory: *Anodonta implicata* (alewife floater), *Elliptio complanata* (eastern Elliptio), *E. cistelliformis* (box spike), *E. emmonsii* (lanceolate Elliptio), *Leptodea ochracea* (tidewater mucket), *Ligumia nasuta* (eastern pondmussel), *Uniomerus* sp. (pondhorn), and *Utterbackia imbecillis* (paper pondshell). Statistics on valve lengths of each species collected can be seen in Table 2b. Reproduction was rare, as a single small *Utterbackia imbecillis* specimen and a few small shells of *E. emmonsii* were noted. The SES for mussels was 2.25.

Elliptio emmonsii (lanceolate Elliptio) was the most common mussel species found during the Bachelor Bay Game Land aquatic inventory. While this species was collected from 8 sites, only 6 live specimens and 22 shells were noted (10 shells were not measurable). Individuals typically were collected in substrata comprised of clay and silt, with some detritus. These areas were typically along or near the stream bank. A few individuals also were found in areas with sand and swampy areas with detritus. The flow regime was typically slack to run at all localities. Time-search abundance estimates of this lance were variable, ranging from < 1 mussel per hour to approximately 30 mussels per hour. Typical abundance estimates were less than 5 mussels per hour.

Utterbackia imbecillis (paper pondshell) and *Elliptio complanata* (eastern Elliptio) were the next most common mussel species, found at 4 and 3 sites, respectively. A total of 2 live specimens and 1 shell of the paper pondshell (shell fragments were found at 2 sites) and 4 live individuals and 3 shells of the eastern Elliptio were collected from the survey area. Both species were typically collected from substrata comprised of clay, silt, and detritus, and the flow regime was slack. Timed searches put the abundance estimates of each species at approximately 1 mussel per hour.

The remaining species were all collected from single sites. *Elliptio cistelliformis* (box spike) and *Uniomerus* sp. (pondhorn) were collected from detritus and silt substrata in a swampy tributary to the Cashie River. *Anodonta implicata* (alewife floater) was collected from sand and detritus substrata along the bank of the Cashie River where the flow regime was run-like. *Leptodea ochracea* (tidewater mucket) and *Ligumia nasuta* (eastern pondmussel) were collected from the Roanoke River in a run to slack flow regime. Both species were found in clay and silt substrata. Abundance estimates for these remaining 5 species ranged from 4 mussels to < 1 mussel per hour.

Over the same time period and at all 28 sites, sphaeriids were collected from 25 localities (Figure 2b and Table 2c), with an overall SES score of 3.34. Eight species were collected during the inventory: *Corbicula fluminea* (Asian clam), *Musculium partumeium* (swamp fingernailclam), *M. securis* (pond fingernailclam), *Pisidium adamsi* (Adam peaclam), *P. casertanum* (ubiquitous peaclam), *P. compressum* (ridged-beak peaclam), *P. ferrugineum* (rusty peaclam), and *P. variabile* (triangular peaclam). *Musculium partumeium* was the dominant sphaeriid, as it was collected from 20 sites. The remaining sphaeriids were collected from 11 or fewer sites. The abundance of each species was variable, ranging from rare to common, with reproduction common to present for all species but the ridged-beak peaclam. *Corbicula fluminea* tended to be common when found, but it was predominantly located in the Roanoke or Middle rivers rather than the tributaries.

In addition to the unionids and sphaeriids, 2 species of brackish water organisms were collected. These species included *Rangia cuneata* (wedge rangia) and *Mytilopsis leucophaeata* (dark falsemussel) (Table 2d).

Lantern Acres Game Land

Over 3 days from 18 July to 20 July 2000, 18 sites were inventoried (site 19 was not surveyed for unionids), and freshwater mussels were collected or observed at 5 sites (Figure 2c and Table 2e). Two species were collected during the inventory: *Pyganodon cataracta* (eastern floater) and *Utterbackia imbecillis* (paper pondshell). Statistics on valve lengths of each species collected can be seen in Table 2f. Reproduction was evident, as the average size of live paper pondshell specimens was approximately 21 mm, and a single adult was gravid. No reproduction was evident for the eastern floater. Both species were relatively rare, with *U. imbecillis* collected from 5 sites and *P. cataracta* from 2 sites. Both species were typically found in detritus and silt, with a few specimens collected in sand. The flow regime of these localities was typically slack with some run. The SES for mussels was 1.97.

Over the same time period and at all 19 sites, sphaeriids were collected from 12 localities (Figure 2d and Table 2g), with an overall SES score of 2.95. Six species were collected during the inventory: *Musculium partumeium* (swamp fingernailclam), *M. transversum* (long fingernailclam), *Pisidium adamsi* (Adam peaclam), *P. casertanum* (ubiquitous peaclam), *P. ferrugineum* (rusty peaclam), and *P. variabile* (triangular peaclam). *Musculium partumeium* was the dominant sphaeriid, as it was collected from 11 sites. The remaining sphaeriids were collected from 5 or fewer sites. The abundance of each species was typically rare to uncommon, with reproduction relatively common for the swamp fingernailclam.

In addition to the unionids and sphaeriids, *Rangia cuneata* (wedge rangia), which is a brackish water clam, was collected from a single site (Table 2h).

Discussion

The overall diversity of the freshwater mussel fauna in Bachelor Bay Game Land and Lantern Acres Game Land and their associated waterways is moderate. Further comparisons to other waterways within these portions of the Roanoke and Pasquotank river basins are hampered due to a lack of surveys. A search of the NCWRC Nongame database did indicate that a total of 12 freshwater mussel species have been collected from the Roanoke River Basin over the past 15 years. However, most of these surveys were conducted in the upper to central portions of the river basin (e.g., Caswell, Person, Granville counties) where the waterways are markedly different than those found in Bertie and Washington counties. Of the 12 species documented in these surveys, 6 were noted in our survey and 6 were not. Our survey also documented the presence of 4 species that had not been previously collected from this area by the NCWRC. Likewise, Johnson (1970) lists a total of 8 species present in the Roanoke River Basin, four of which we documented during this inventory. The remaining species are likely present in the upper portions of the river basin based on the NCWRC Nongame database information. Two of the species that our survey had in common with Johnson's list were those that the NCWRC had not documented prior to this survey. This leaves us with a total of 2 previously undocumented species (*Utterbackia imbecillis* and *Elliptio cistelliformis*) from the lower reach of the Roanoke River Basin. Comparisons to the Pasquotank River Basin are not possible, since the NCWRC database does not include any additional records, and Johnson (1970) includes this river basin with the Pamlico, which make any comparisons tenuous at best.

Current distribution patterns and ranges of the sphaeriid fauna are much less understood than those for the freshwater mussel fauna. The location of 8 sphaeriid species at 36 sites (excluding *Corbicula fluminea*) is relatively high when compared to additional statewide aquatic inventories conducted by the authors. A search of the NCWRC Nongame database did not return any results from these portions of the Roanoke and Pasquotank river basins for comparison.

The water body types that we encountered during our survey were relatively heterogeneous, with some sites representing true swamps, some having more Piedmont-like characteristics, and some comprising ditches and canals. Given the wide range of available habitat types, it is not atypical to discover a moderate to high freshwater mussel diversity, since they are typically more successful in areas with diverse habitat types (see Background, Habitat Requirements). Given these factors, it was not surprising to find a relatively high number of sphaeriid species as well. It also is likely that the influence of geomorphologic and topographic factors have significantly affected the current unionid and sphaeriid fauna. Major landscape scale factors such as these are known to influence and impact the distributions and abundances of organisms over time, and it is possible that the area we surveyed has naturally moderate to high presence of freshwater bivalves. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture, logging, and industry within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration, sedimentation, and point-source discharge. Effects from urbanization appeared to be minimal given most of the surveyed area is rural, but impacts are likely felt from upstream sources like Roanoke Rapids. The practice of ditching for drainage purposes was commonly evident in some areas and also has likely had a significant effect on the current freshwater bivalve composition of the area. Given past surveys and the SES ranging from approximately 2.0 to 2.25 for freshwater mussels, it is likely that our survey efforts resulted in a representative sample of the freshwater mussel fauna of the area. Likewise, with the average SES over 3 for sphaeriids, we likely captured a representative sample of the area's diversity.

The collection of *Anodonta implicata*, *Leptodea ochracea*, and *Ligumia nasuta* are all significant collections, since these species currently have some type of special designation. All 3 species are currently state-listed special concern but proposed as state threatened. The presence of these populations suggests that opportunities are still available for conservation and potential future down listing or delisting of these species.

While 3 imperiled freshwater mussel species were collected during the survey of Bachelor Bay and Lantern Acres game lands, continual research and status surveys are needed to determine the present status of all bivalve species. *Musculium partumeium* and *Pisidium adamsi* are currently considered species of undetermined status (Adams 1990), but recent surveys by the authors have shown these species to be common across the Coastal Plain and parts of the Piedmont. Current land management practices, including agriculture and urbanization, are having an effect on the bivalve fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

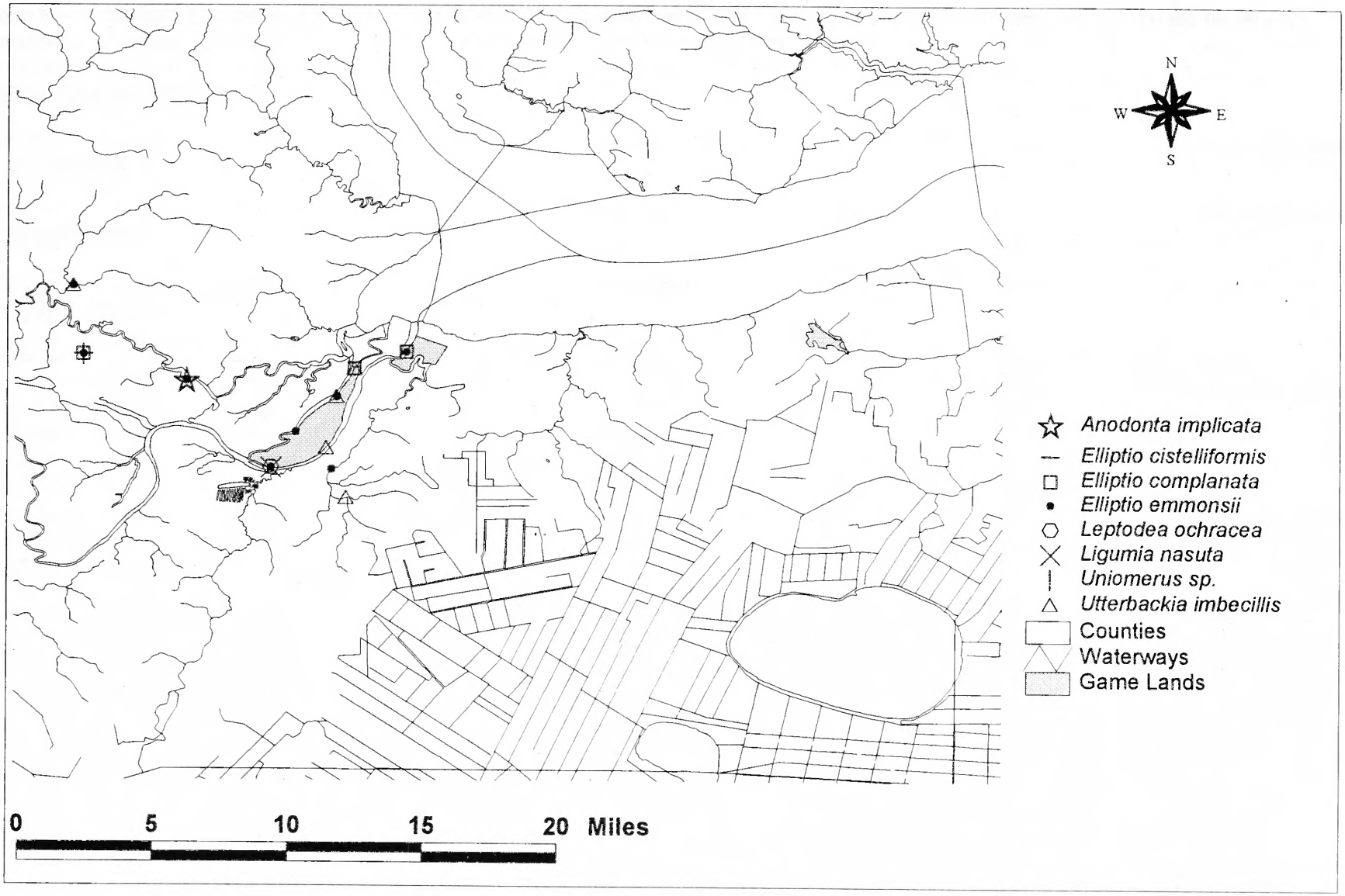

Figure 2a. Map of sites indicating where each species of freshwater mussel was collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

Table 2a. Freshwater mussel species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Anodonta implicata							
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	rare	J.M. Alderman
Elliptio cistelliformis							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	J.M. Alderman
Elliptio complanata							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson, J.M. Alderman
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson, J.M. Alderman
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Elliptio emmonsii							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	B.T. Watson
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	rare	B.T. Watson, J.M. Alderman
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	common	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson, J.M. Alderman
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Leptodea ochracea							
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	J.M. Alderman
Ligumia nasuta							
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	J.M. Alderman, B.T. Watson
***Uniomerus* sp.**							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	present	B.T. Watson, J.M. Alderman
Utterbackia imbecillis							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	present	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson

Table 2b. Statistics on valve lengths of live freshwater mussels and shells found in Bachelor Bay Game Land and associated waterways. See text for common names.

	Avg	Std	Min	Max
Anodonta implicata				
live (1 record)	111.0		111.0	111.0
shell (1 record)	83.0		83.0	83.0
Species Total (2 records)	97.0	19.8	83.0	111.0
Elliptio cistelliformis				
shell (4 records)	73.8	5.3	67.0	78.0
Species Total (4 records)	73.8	5.3	67.0	78.0
Elliptio complanata				
live (4 records)	86.8	15.7	66.0	102.0
shell (3 records)	51.7	7.8	43.0	58.0
Species Total (7 records)	71.7	22.2	43.0	102.0
Elliptio emmonsii				
live (6 records)	105.3	34.9	43.0	145.0
shell (12 records)	69.3	23.4	34.0	109.0
Species Total (18 records)	81.3	31.9	34.0	145.0
Leptodea ochracea				
live (5 records)	114.4	9.9	101.0	124.0
Species Total (5 records)	114.4	9.9	101.0	124.0
Ligumia nasuta				
live (2 records)	97.0	1.4	96.0	98.0
shell (1 record)	106.0		106.0	106.0
Species Total (3 records)	100.0	5.3	96.0	106.0
Ligumia nasuta/Elliptio emmonsii				
live (6 records)	94.3	9.5	78.0	107.0
Species Total (6 records)	94.3	9.5	78.0	107.0

Table 2b (cont.). Statistics on valve lengths of live freshwater mussels and shells found in Bachelor Bay Game Land and associated waterways. See text for common names.

	Avg	Std	Min	Max
Uniomerus sp.				
shell (1 record)	62.0		62.0	62.0
Species Total (1 record)	62.0		62.0	62.0
Utterbackia imbecillis	**Avg**	**Std**	**Min**	**Max**
live (2 records)	38.5	24.7	21.0	56.0
shell (1 record)	75.0		75.0	75.0
Species Total (3 records)	50.7	27.4	21.0	75.0

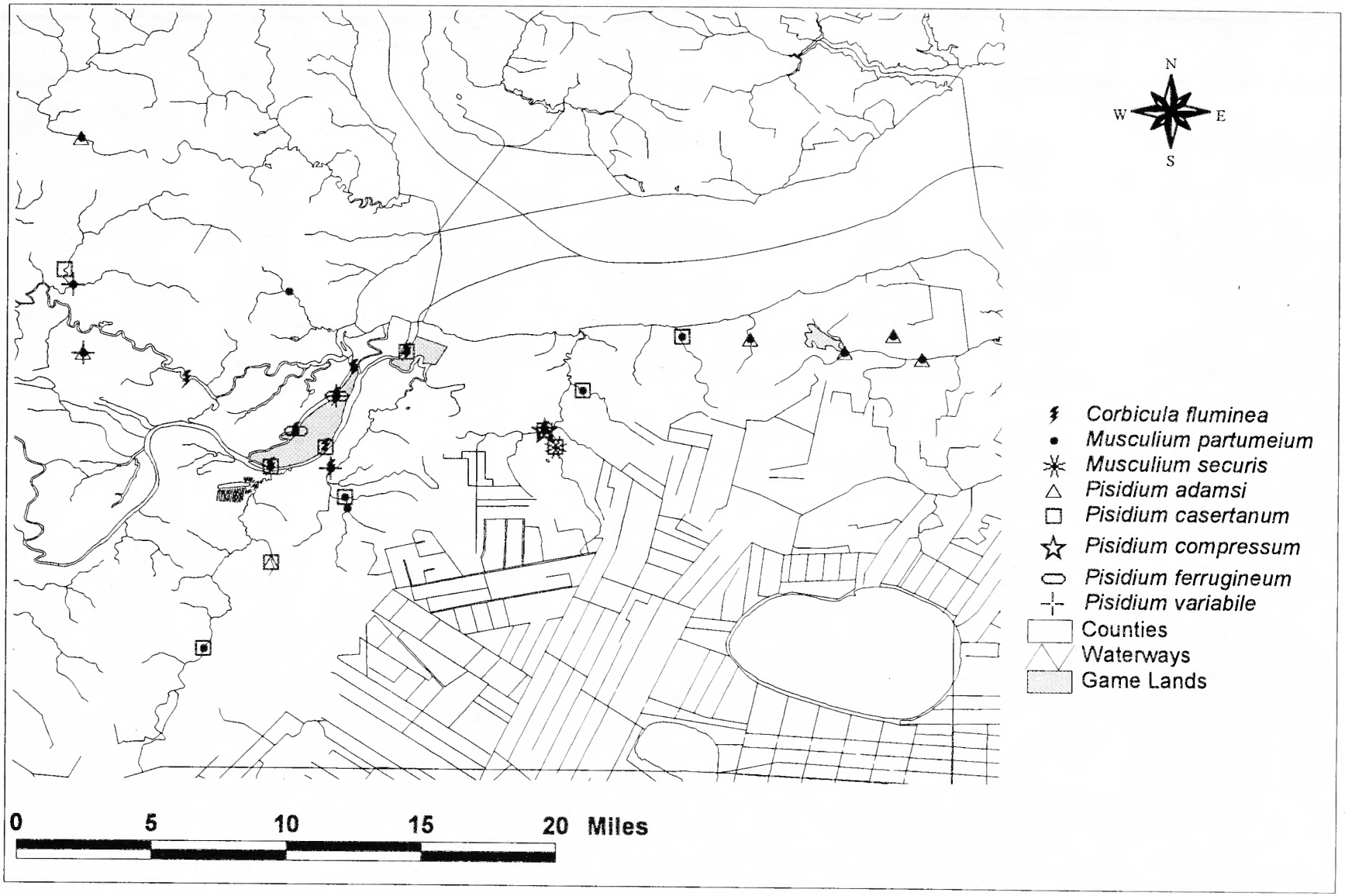

Figure 2b. Map of sites indicating where each species of sphaeriid clam was collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

Table 2c. Sphaeriid clam species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Corbicula fluminea							
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	uncommon	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	common	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	common	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	abundant	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	common	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	common	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	common	B.T. Watson
Musculium partumeium							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	uncommon	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	patchy uncommon	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	patchy uncommon	B.T. Watson
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Creek	SR 1001 -	patchy uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Creek	SR 1115	present	B.T. Watson
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	uncommon	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	uncommon	B.T. Watson
000622.4btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1302 -	rare	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	uncommon	B.T. Watson, G.L. Mackie
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	patchy uncommon	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson, G.L. Mackie
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	patchy common	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	uncommon	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	patchy uncommon	B.T. Watson

Table 2c (cont.). Sphaeriid clam species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Musculium securis							
000817.3btw	8/17/2000	Pasquotank	Washington	Trib to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	common	G.L. Mackie, B.T. Watson
Pisidium adamsi							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	patchy common	B.T. Watson
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Creek	SR 1001 -	patchy common	B.T. Watson, G.L. Mackie
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	rare	B.T. Watson, G.L. Mackie
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	uncommon	B.T. Watson, G.L. Mackie
000622.4btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1302 -	rare	B.T. Watson, G.L. Mackie
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	rare	B.T. Watson, G.L. Mackie
000808.2btw	8/8/2000	Roanoke	Washington	Tributary to Welch Creek	Bike 3/SR 1100 -	patchy common	B.T. Watson, G.L. Mackie
Pisidium casertanum							
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	rare	B.T. Watson, G.L. Mackie
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	rare	B.T. Watson
000808.2btw	8/8/2000	Roanoke	Washington	Tributary to Welch Creek	Bike 3/SR 1100 -	present	B.T. Watson, G.L. Mackie
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	G.L. Mackie
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson, G.L. Mackie
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson, G.L. Mackie
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	present	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	rare	B.T. Watson, G.L. Mackie
000817.3btw	8/17/2000	Pasquotank	Washington	Trib to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	rare	B.T. Watson, G.L. Mackie
Pisidium compressum							
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	G.L. Mackie
Pisidium ferrugineum							
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	G.L. Mackie
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	G.L. Mackie

Table 2c (cont.). Sphaeriid clam species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Pisidium variabile							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	patchy uncommon	G.L. Mackie
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	rare	G.L. Mackie
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	G.L. Mackie
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	G.L. Mackie

Table 2d. Brackish water species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Rangia cuneata							
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	patchy uncommon	B.T. Watson
Mytilopsis leucophaeata							
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	patchy uncommon	B.T. Watson

Figure 2c. Map of sites indicating where each species of freshwater mussel was collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

Table 2e. Freshwater mussel species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Pyganodon cataracta							
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	present	B.T. Watson
Utterbackia imbecillis							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	rare	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	uncommon	B.T. Watson
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	present	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	uncommon	B.T. Watson

Table 2f. Statistics on valve lengths of live freshwater mussels and shells found in Lantern Acres Game Land and associated waterways. See text for common names.

Pyganodon cataracta	Avg	Std	Min	Max
live (1 record)	125.0		125.0	125.0
shell (1 record)	133.0		133.0	133.0
Species Total (2 records)	129.0	5.7	125.0	133.0

Utterbackia imbecillis	Avg	Std	Min	Max
live (15 records)	21.1	15.2	10.0	69.0
shell (2 records)	73.5	3.5	71.0	76.0
Species Total (17 records)	27.3	22.5	10.0	76.0

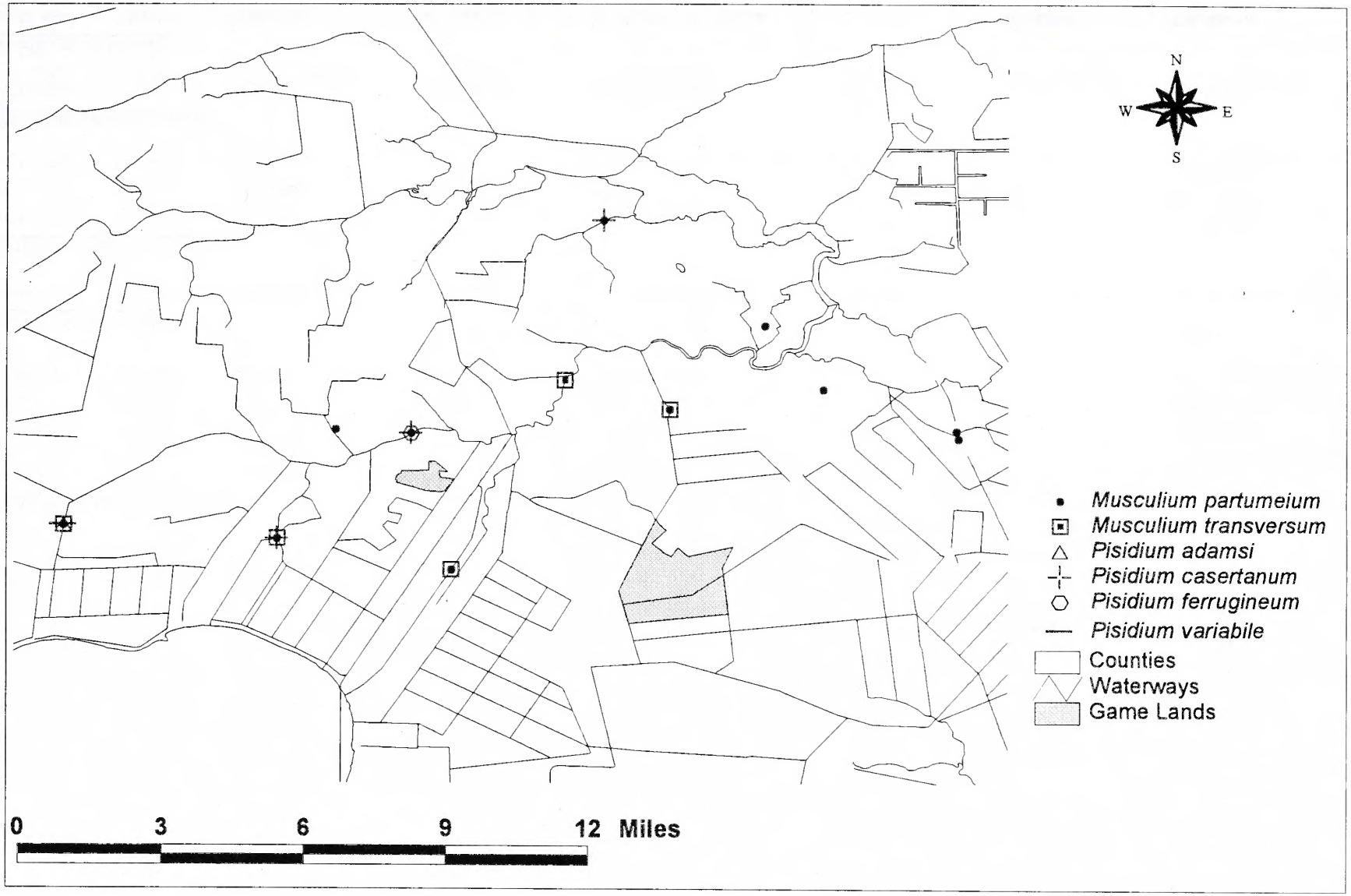

Figure 2d. Map of sites indicating where each species of sphaeriid clam was collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

Table 2g. Sphaeriid clam species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Musculium partumeium							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	rare	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	common	B.T. Watson, G.L. Mackie
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	uncommon	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	abundant	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	patchy common	B.T. Watson
000719.6btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1110	rare	B.T. Watson, G.L. Mackie
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	rare	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	rare	B.T. Watson
000720.4btw	7/20/2000	Pasquotank	Tyrrell	Swampy trib near Second Ck	NC 94	rare	B.T. Watson, G.L. Mackie
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	abundant	B.T. Watson
Musculium transversum							
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	present	B.T. Watson
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	rare	B.T. Watson, G.L. Mackie
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson, G.L. Mackie
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	present	B.T. Watson, G.L. Mackie
Pisidium adamsi							
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	uncommon	B.T. Watson, G.L. Mackie
Pisidium casertanum							
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	G.L. Mackie
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	rare	G.L. Mackie
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	rare	G.L. Mackie
Pisidium ferrugineum							
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	present	G.L. Mackie
Pisidium variabile							
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	uncommon	G.L. Mackie

Table 2h. Brackish water species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Rangia cuneata							
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	present	B.T. Watson

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AQUATIC SNAILS

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Introduction

Freshwater snails (Mollusca: Gastropoda) are among the most ubiquitous organisms of shallow littoral zones in lakes and streams. Due to their behavior, widespread distribution, and commonly high abundance, snails serve a number of important roles in aquatic ecosystems. These include driving predator-prey interactions (Vermeij and Covich 1978, Lodge et al. 1987), serving as a dietary component to fish and wildlife, acting as water quality indicators, and most importantly, grazing on nuisance algae and detritus. However, freshwater snails are often overlooked in part due to their small size, perceived lack of charisma, cryptic habits, and the lack of readily available comprehensive guides for identification. As part of the inventory of aquatic animals associated with the state-owned Bachelor Bay Game Land and Lantern Acres Game Land, we conducted field surveys of aquatic snails found in waterways occurring in and around the game lands to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

Much information about the reproductive cycles of freshwater snails has been ascertained due to the ease of laboratory rearing. From this information, 2 typical categories have been developed in which snails can be placed reproductively (Russell-Hunter 1978, Calow 1978). The first category includes annual adults that reproduce in the spring and die (semelparous). Most pulmonates (lung breathing), which are oviparous hermaphrodites, belong to this group including the genera *Lymnaea* and *Physa*. The second category includes perennial adults that reproduce in both spring and late summer. Most prosobranchs (gill breathing), which are dioecious and can be oviparous or ovoviviparous, belong to this group. These species are iteroparous and often live and reproduce for 4-5 years. Prosobranchs also are often sexually dimorphic, with females living longer than males (Brown et al. 1989).

Habitat and Food Requirements

Freshwater snails occupy a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with well-documented substratum selection (Brown 1991). In general, silty habitats with slow-moving currents are colonized predominately by pulmonates or detritivorous prosobranchs, whereas limpets or prosobranch grazers colonize fast-current localities (Harman 1972). Many biotic and abiotic factors regulate the distribution of freshwater snails, with water hardness and pH considered to be the major determinants (Macan 1950, Pip 1986). However, it has been suggested that physiochemical factors such as calcium concentrations may only act to limit successful invasion of habitats with extreme levels of these factors (Lodge et al. 1987). Other factors such as dispersal ability and adequate substrata may play a more prominent role in snail distribution.

Freshwater snails are predominantly herbivores or detritivores, although they can ingest carrion (Bovbjerg 1968) or passively consume small invertebrates associated with periphyton (Cuker 1983a). Apparently, they prefer periphyton because it is easier to scrape than macrophytes, and it contains higher concentrations of nitrogen and other limiting nutrients (Russell-Hunter 1978, Aldridge 1983). Algae and diatoms also are prominent sources of nutrients for freshwater snails (Lodge 1986). While macrophytes are not the preferred source of nutrients for most freshwater snails, significant consumption can occur if snail densities reach high levels (Sheldon 1987).

Taxonomy, Distribution, and Statuses

Freshwater snails are divided into 2 groups – prosobranchs and pulmonates. Prosobranch snails are gill breathing and have a calcareous plate called an operculum that seals the aperture when the snail withdraws into its shell. Pulmonate snails are lung breathing and lack an operculum. Of the approximately 500 species recognized in North America, there are 49 genera and 349 species of prosobranch snails and 29 genera and 150 species of pulmonate snails (Burch 1982). While snails are widespread across the continent, they have reached their greatest abundance and diversity within the streams of the southeastern United States (Brown 1991). In North Carolina, there are approximately 52 species representing 10 families (Bogan 1997). Since very little work has been done to monitor freshwater snail populations, the current status of many species within North Carolina is undetermined. It is unknown as to the magnitude of impact that anthropogenic effects, such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration have had on the state's snail fauna. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The aquatic snail survey of Bachelor Bay Game Land and Lantern Acres Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points, and the Roanoke and Middle rivers were surveyed via motorboat. Since most waterways were swamps, canals, or ditches, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Freshwater snails were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common methods used to sample the snail fauna were visual searches and dip netting. The visual search basically involved examining rocky substrata, woody debris, vegetation, cans and bottles, and other items that snails might colonize. Dip netting involved running a 1/8-inch mesh dip net through vegetation and the substrata to collect snails. Other techniques used to collect snails included tactile searches, the use of a viewscope, and raking of the substrata. Habitat preference, relative abundance, and recent reproduction for snail species were noted at each site. Snails were preserved in 70% ethanol and identified according to Burch (1989) and Basch (1963). Scientific names are according to Turgeon et al. (1998). Dr. Arthur E. Bogan, curator of aquatic invertebrates at the NC State Museum of Natural Sciences, verified some of the species

identifications. Not all snails collected were preserved for obvious conservation and ethical reasons.

For aquatic snails, a survey effectiveness score (SES) was determined at each site (if possible) and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Bachelor Bay Game Land

Over 8 days from 13 June to 17 August 2000, 28 sites were inventoried, and aquatic snails were collected or observed at 25 localities (Figures 3a-c). At least 13 species representing 6 families were documented during the Bachelor Bay Game Land survey (Tables 3a and 3b). Due to the difficulty of identifying hydrobiids (see Discussion), we have identified all specimens to family for this report. The relative abundance of each species varied, but a number of species were well distributed over the survey area. These species included *Ferrissia* sp., *Physella* sp., *Micromenetus dilatatus*, and *Pseudosuccinea columella*, which were present at 20, 19, 18, and 16 sites, respectively (Figures 3a-c). Due to species level variation and the uncertainty of positively discerning *Ferrissia* specimens, all specimens of this genus were identified as *Ferrissia* sp. Likewise, all *Physella* specimens were identified to genus only, since the soft parts were not examined. The remaining snail species were represented over a smaller number of sites, ranging from 1-11. Regardless of the number of sites from which a particular species was collected, abundances were typically variable between sites, ranging from rare to abundant. Recent reproduction was seen at a number of sites for all the snail species collected during the survey. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and Hydrobiidae), it was difficult to confirm whether these were adults or juveniles, and typically reproduction was not recorded. The SES for aquatic snails was 3.43.

Ferrissia sp., *Laevapex fuscus* (dusky ancylid), *Micromenetus dilatatus* (bugle sprite), *Gyraulus deflectus* (flexed gyro), and *Promenetus exacuous* (sharp sprite) were typically found in areas with slow to moderate flow on aquatic vegetation and woody debris. These species also were found on cans and bottles, with the ancylids being especially common on these items.

Physella sp. (physa snail), *Campeloma decisum* (pointed campeloma), *Fossaria humilis* (marsh fossaria), *Pseudosuccinea columella* (mimic lymnaea), *Planorbella duryi* (Seminole rams-horn), *Planorbella trivolvis/Helisoma anceps* (marsh/two-ridge rams-horn), and *Planorbula armigera* (thicklip rams-horn) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the stream bank, behind sandbars, or wherever the conditions were swamp-like. *C. decisum* was found predominantly in sand and detritus, but occasionally an individual was found on the clay banks or on woody debris or vegetation. The marsh fossaria was found in detritus and on woody debris. *Physella* sp. *and P. columella* typically were found on aquatic vegetation and woody debris, while occasionally residing along the clay and mud banks. The rams-horns were typically associated with detritus and vegetation in stagnant and backwater areas.

Hydrobiids were collected from areas ranging from swamp-like to run-like flow. Specimens tended to be common on woody debris but also were collected from detritus and vegetation.

Lantern Acres Game Land

Over 3 days from 18 July to 20 July 2000, 19 sites were inventoried and aquatic snails were collected or observed at all 19 localities (Figures 3d-f). At least 12 species representing 5 families were documented during the Lantern Acres Game Land survey (Tables 3c and 3d). Due to the difficulty of identifying hydrobiids (see Discussion), we have identified all specimens to family for this report. The relative abundance of each species varied, but a number of species were well distributed over the survey area. These species included *Physella* sp., *Pseudosuccinea columella*, *Ferrissia* sp., and *Micromenetus dilatatus*, which were present at 13, 12, 11, and 10 sites, respectively (Figures 3d-f). Due to species level variation and the uncertainty of positively discerning *Ferrissia* specimens, all specimens of this genus were identified as *Ferrissia* sp. Likewise, all *Physella* specimens were identified to genus only, since the soft parts were not examined. The remaining snail species were represented over a smaller number of sites, ranging from 1-5. Regardless of the number of sites from which a particular species was collected, abundances were typically rare to uncommon. Recent reproduction was seen at a number of sites for all the snail species collected during the survey except the rams-horns. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and Hydrobiidae), it was difficult to confirm whether these were adults or juveniles, and typically reproduction was not recorded. The SES for aquatic snails was 3.08.

Ferrissia sp., *Laevapex fuscus* (dusky ancylid), *Micromenetus dilatatus* (bugle sprite), *Gyraulus deflectus* (flexed gyro), and *Promenetus exacuous* (sharp sprite) were typically found in areas with slow to moderate flow on aquatic vegetation and woody debris. These species also were found on cans and bottles, with the ancylids being especially common on these items.

Physella sp. (physa snail), *Campeloma decisum* (pointed campeloma), *Fossaria humilis* (marsh fossaria), *Pseudosuccinea columella* (mimic lymnaea), *Planorbella duryi* (Seminole rams-horn), *Planorbella trivolvis* (marsh rams-horn), and *Planorbula armigera* (thicklip rams-horn) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the stream bank, behind sandbars, or wherever the conditions were swamp-like. *Fossaria humilis* was found in temporary pools created by vehicles at a boat ramp. *Physella* sp. *and P. columella* typically were found on aquatic vegetation and woody debris, while occasionally residing along the clay and mud banks. The rams-horns were typically associated with detritus and vegetation in stagnant, backwater areas, and ditches and canals.

Hydrobiids were collected from areas ranging from swamp-like to run-like flow. Specimens tended to be common on woody debris but also were collected from detritus and vegetation.

Discussion

Overall, the diversity and abundance of freshwater snails in the waterways associated with the Bachelor Bay Game Land and the Lantern Acres Game Land appear to be moderate to high. The results reported here are typical of additional state-wide aquatic inventories conducted by the authors. Further comparisons are hampered due to a lack of survey information for this part of the state. Given the relative diversity of habitat types and flow regimes encountered, it was not surprising that we found a relatively healthy number of gastropod species. It also is likely that

the influence of geomorphologic and topographic factors have significantly affected the current gastropod fauna. Major landscape scale factors such as these are known to influence and impact the distribution and abundance of organisms over time. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture, logging, and industry within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration, sedimentation, and point-source discharge. Effects from urbanization appeared to be minimal given most of the surveyed area is rural, but impacts are likely felt from upstream sources like Roanoke Rapids. The practice of ditching for drainage purposes was commonly evident in some areas and has likely had a significant effect on the current freshwater gastropod composition of the area. These land use impacts may have been the primary dynamic contributing to some of the species' limited distributions and their relatively low abundances. Since the SES was over 3.0 for both game lands, our survey efforts were relatively sufficient to have captured an accurate reflection of the aquatic snail composition of the area.

Taxonomic uncertainties within the freshwater snail fauna make the results here subject to revision. For example, the differentiation between *F. rivularis* and *F. fragilis* is difficult due to shell shape variation. Therefore, a common factor used to distinguish these species is the habitat they are collected in, with *F. rivularis* colonizing rivers and streams and *F. fragilis* inhabiting stagnant areas such as ditches, ponds, and backwater areas (Burch 1989). All of the limpets identified in this survey were assigned to *Ferrissia* sp., but it is possible that at least both species inhabit some of the sites that were surveyed. Some of the *Ferrissia* sp. field identifications could also have been *Laevapex fuscus* given the difficulty in sometimes differentiating smaller specimens in the field. Additionally, a number of rams-horn specimens were field identified as *Helisoma anceps* but preserved material was later correctly identified as *Planorbella trivolvis*. Specimens identified as both species are most likely the marsh rams-horn, since all preserved specimens were lab identified as this species. Likewise, many uncertainties exist as to the taxonomy of *Physella* and hydrobiids without examination of soft parts (Burch 1989). Since we did not preserve the specimens for the examination of soft parts, we identified *Physella* specimens to genus only and hydrobiid specimens to family.

The collection of *Planorbella duryi* in the Roanoke and Pasquotank river basins is significant, as these are the third and fourth river basins the species has been recorded from in North Carolina. The Seminole rams-horn was recently recorded from the White Oak River Basin (Watson and Fullerton 2001a) and the Neuse River Basin (Watson and Fullerton 2001b), making these the first records of the species in North Carolina (Bogan 1997). The historical distribution of this species is described as extending from northern to southern Florida (Burch 1989). It is believed this species was introduced through the aquaria trade (A.E. Bogan, NCSM, pers. comm.). On a past trip to a local aquarium shop, Bogan viewed specimens of the Seminole rams-horn on aquatic vegetation that had been shipped from Florida. However, it is possible that the specimens we have identified as *P. duryi* are actually *Planorbella trivolvis*. Baker (1945) shows a photograph of an aquarium raised marsh rams-horn that looks like the Seminole rams-horn, and comments on their similarity.

While no threatened or endangered gastropod species was collected during the survey of Bachelor Bay and Lantern Acres game lands, continual research and status surveys are needed to determine the present status of each species. The status of *Gyraulus deflectus* is considered

possibly imperiled but undetermined due to a lack of information (Adams 1990), which may be in part due to misidentification of the species given its small size and similarity to other planorbids. Current land management practices, including agriculture and urbanization, are having an effect on the snail fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

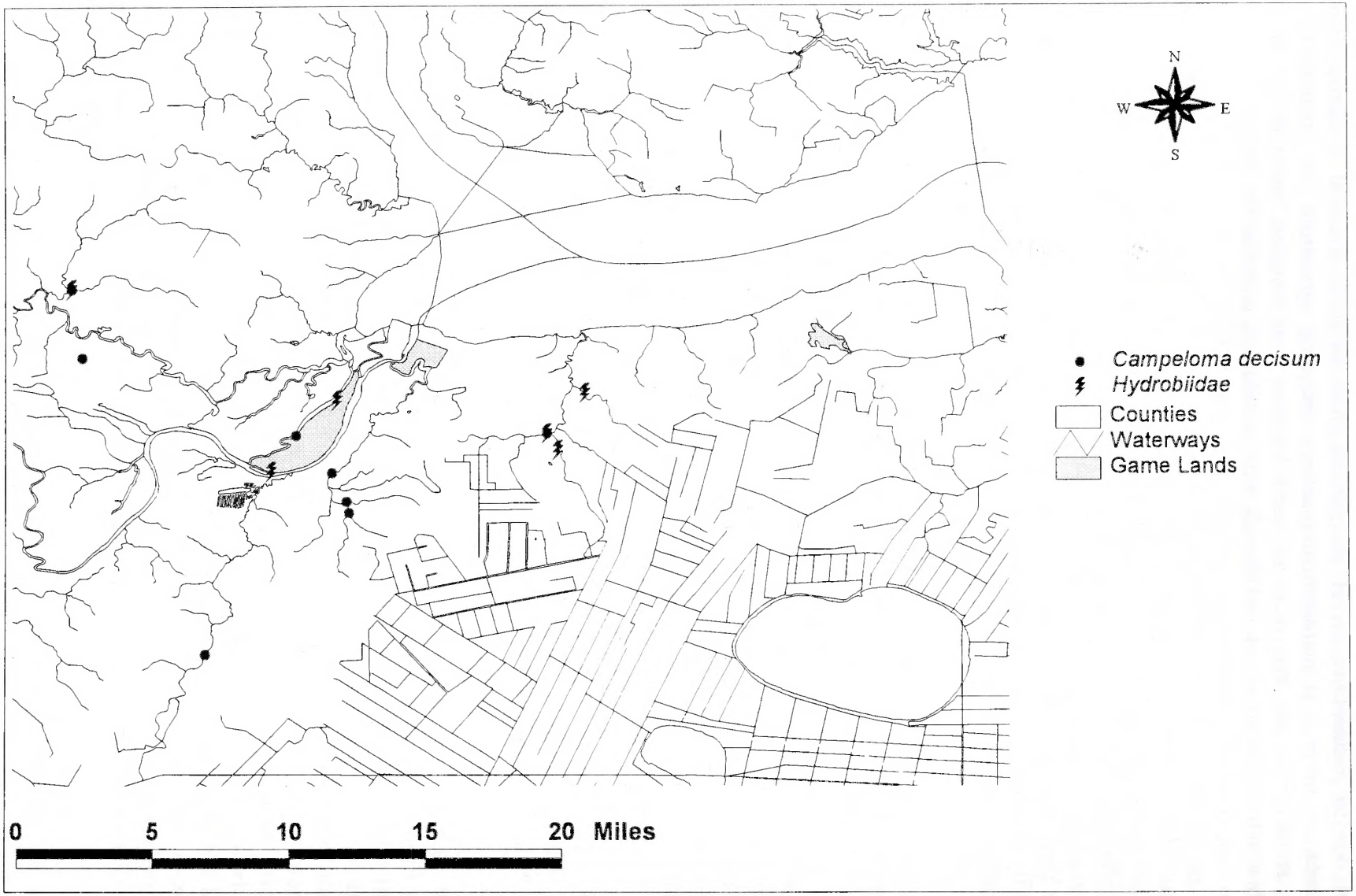

Figure 3a. Map of sites indicating where each species of prosobranch snail was collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

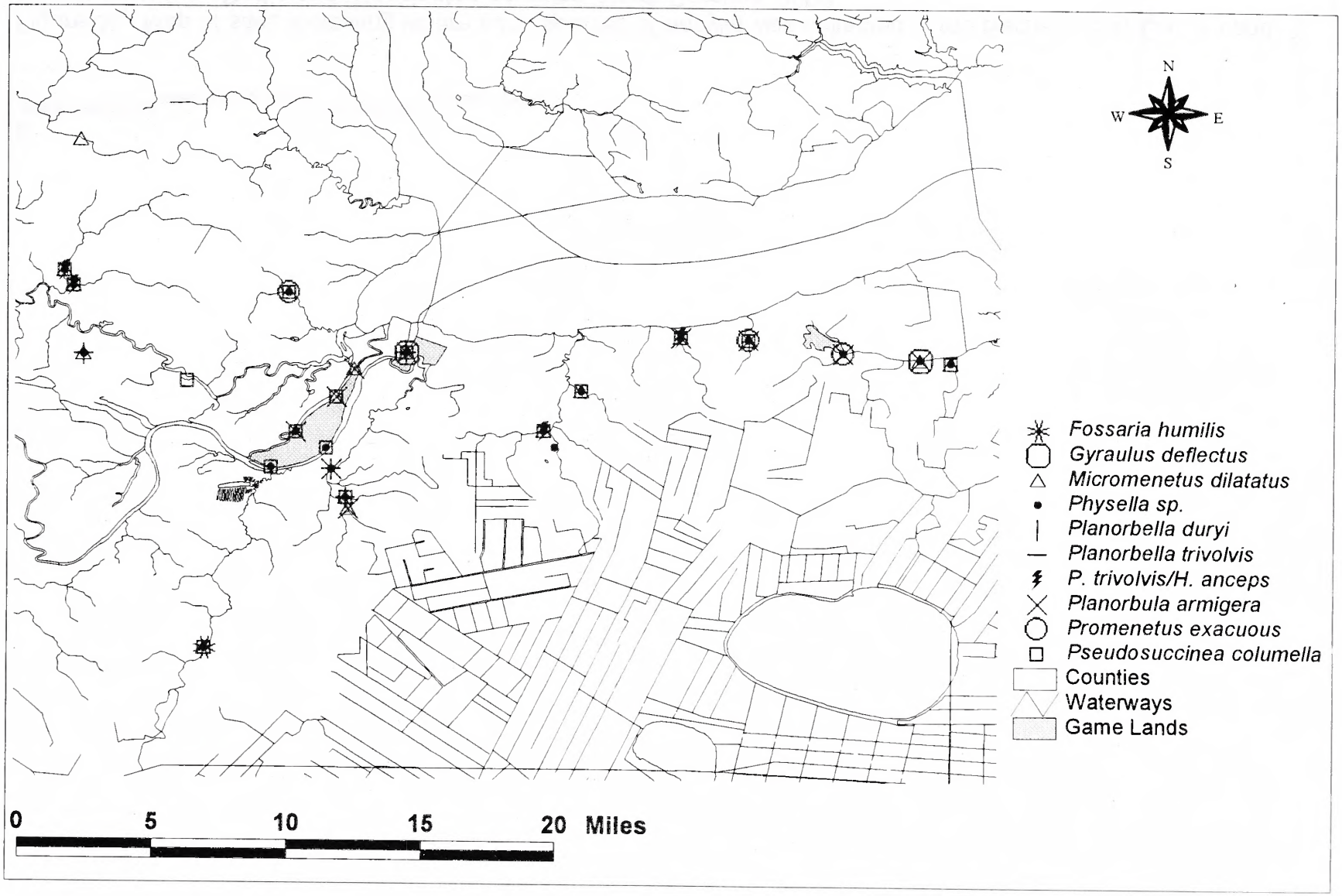

Figure 3b. Map of sites indicating where each species of pulmonate snail was collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

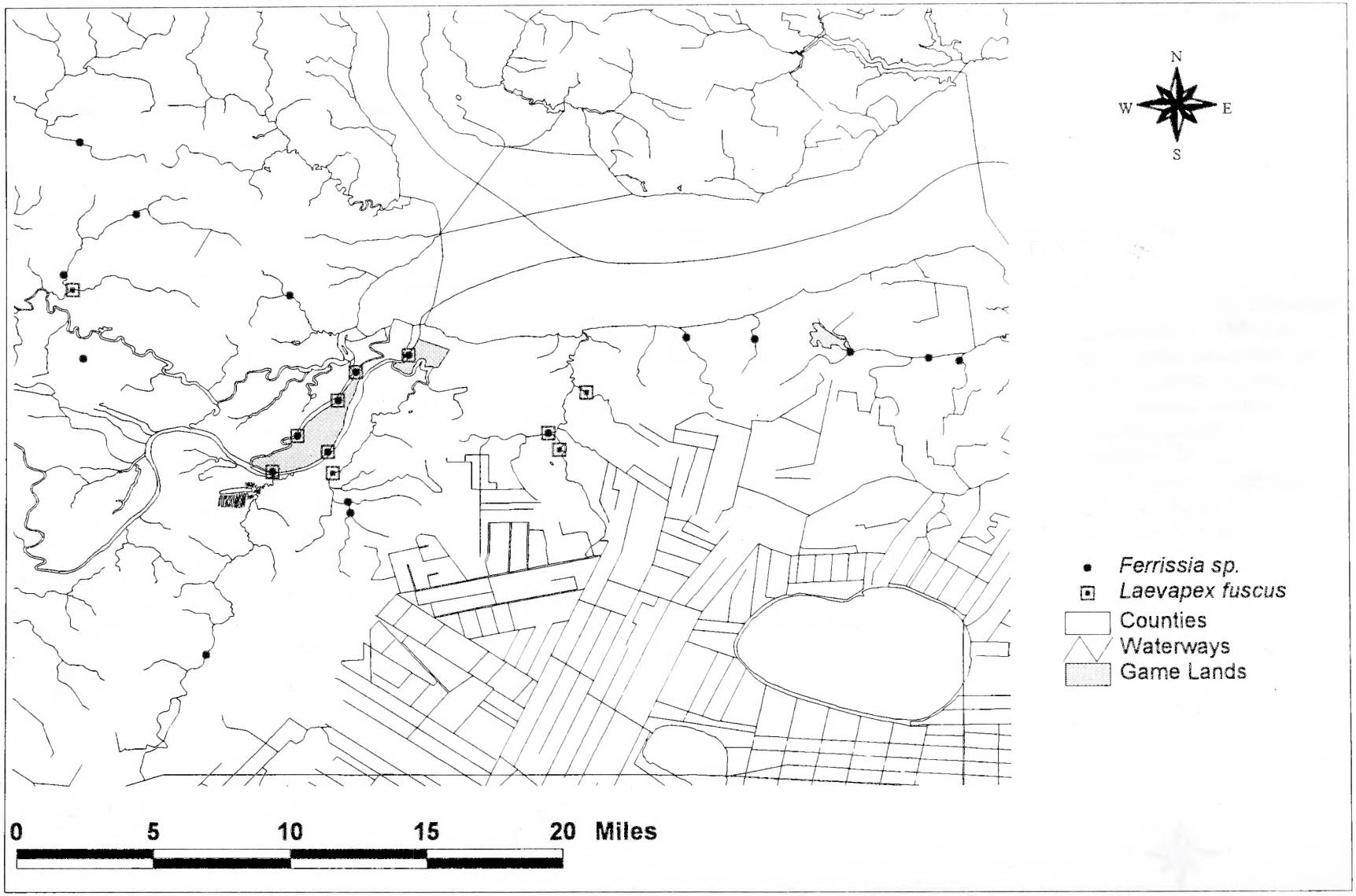

Figure 3c. Map of sites indicating where each species of ancylid was collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

Table 3a. Aquatic snail species found in Bachelor Bay Game Land and associated waterways.

Prosobranchia	
Hydrobiidae	hydrobiid
Viviparidae	
Campeloma decisum	pointed campeloma
Pulmonata	
Ancylidae	
Ferrissia sp.	limpet
Laevapex fuscus	dusky ancylid
Lymnaeidae	
Fossaria humilis	marsh fossaria
Pseudosuccinea columella	mimic lymnaea
Physidae	
Physella sp.	physa snail
Planorbidae	
Gyraulus deflectus	flexed gyro
Micromenetus dilatatus	bugle sprite
Planorbella duryi	Seminole rams-horn
Planorbella trivolvis/Helisoma anceps	marsh/two-ridge rams-horn
Planorbula armigera	thicklip rams-horn
Promenetus exacuous	sharp sprite

Table 3b. Aquatic snail species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Campeloma decisum							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	abundant	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Ck	SR 1115	present	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	common	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	patchy common	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
***Ferrissia* sp.**							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	rare	B.T. Watson
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	uncommon	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	uncommon	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	rare	B.T. Watson
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Ck	SR 1001 -	patchy uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Ck	SR 1115	present	B.T. Watson
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	patchy common	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	rare	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	patchy uncommon	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	patchy rare	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	patchy common	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	rare	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	uncommon	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	abundant	B.T. Watson

Table 3b (cont.). Aquatic snail species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Fossaria humilis							
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson, A.E. Bogan
Gyraulus deflectus							
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	common	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Hydrobiidae							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	common	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	rare	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	patchy rare	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Trib to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	rare	B.T. Watson
Laevapex fuscus							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	uncommon	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	patchy uncommon	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	rare	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	common	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	uncommon	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	patchy common	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	uncommon	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Trib to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	common	B.T. Watson

Table 3b (cont.). Aquatic snail species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Micromenetus dilatatus							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	uncommon	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	rare	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	patchy common	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	patchy uncommon	B.T. Watson
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Ck	SR 1001 -	patchy common	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Ck	SR 1115	present	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	rare	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	uncommon	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	uncommon	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	rare	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	uncommon	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	patchy uncommon	B.T. Watson
***Physella* sp.**							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	uncommon	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	uncommon	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	common	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	rare	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	rare	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	uncommon	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	patchy uncommon	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	patchy uncommon	B.T. Watson

Table 3b (cont.). Aquatic snail species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
***Physella* sp.**							
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	rare	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	present	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	rare	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Trib to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	rare	B.T. Watson
Planorbella duryi							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
***Planorbella* sp.**							
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson, A.E. Bogan
Planorbella trivolvis							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Planorbella trivolvis/Helisoma anceps							
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	rare	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	rare	B.T. Watson

Table 3b (cont.). Aquatic snail species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Planorbula armigera							
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Ck	SR 1115	present	B.T. Watson
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	uncommon	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	rare	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	abundant	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	present	B.T. Watson
Promenetus exacuous							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	rare	B.T. Watson
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	uncommon	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	abundant	B.T. Watson
Pseudosuccinea columella							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	uncommon	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	rare	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	common	B.T. Watson
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	rare	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	rare	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	patchy rare	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	patchy common	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	rare	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	common	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	patchy uncommon	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	rare	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	patchy uncommon	B.T. Watson

Figure 3d. Map of sites indicating where each species of prosobranch snail was collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

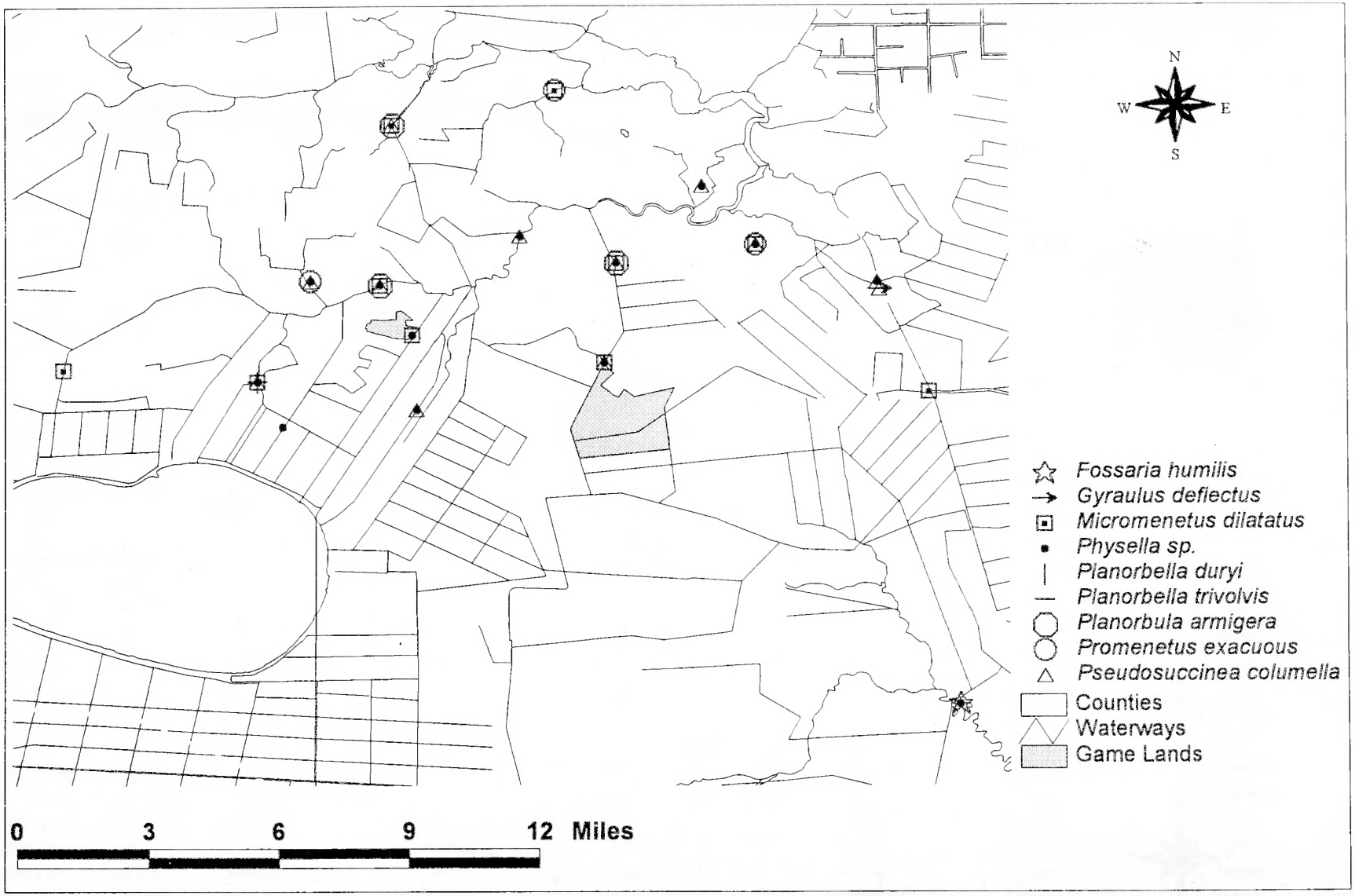

Figure 3e. Map of sites indicating where each species of pulmonate snail was collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

Figure 3f. Map of sites indicating where each species of ancylid was collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

Table 3c. Aquatic snail species found in Lantern Acres Game Land and associated waterways.

Prosobranchia	
Hydrobiidae	hydrobiid
Pulmonata	
Ancylidae	
Ferrissia sp.	limpet
Laevapex fuscus	dusky ancylid
Lymnaeidae	
Fossaria humilis	marsh fossaria
Pseudosuccinea columella	mimic lymnaea
Physidae	
Physella sp.	physa snail
Planorbidae	
Gyraulus deflectus	flexed gyro
Micromenetus dilatatus	bugle sprite
Planorbella duryi	Seminole rams-horn
Planorbella trivolvis	marsh rams-horn
Planorbula armigera	thicklip rams-horn
Promenetus exacuous	sharp sprite

Table 3d. Aquatic snail species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
***Ferrissia* sp.**							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	patchy common	B.T. Watson
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	rare	B.T. Watson
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	rare	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	present	B.T. Watson
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR1201(T)	rare	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	patchy common	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	patchy rare	B.T. Watson
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	patchy common	B.T. Watson
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	present	B.T. Watson
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	rare	B.T. Watson
000720.5btw	7/20/2000	Pasquotank	Tyrrell	Canal trib to Riders Creek	SR 1301 near SR 1303	rare	B.T. Watson
Fossaria humilis							
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	patchy abundant	B.T. Watson
Gyraulus deflectus							
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	rare	B.T. Watson
Hydrobiidae							
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	patchy rare	B.T. Watson, A.E. Bogan
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	rare	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson, A.E. Bogan
Laevapex fuscus							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	rare	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	patchy rare	B.T. Watson
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	rare	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	present	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	present	B.T. Watson

Table 3d (cont.). Aquatic snail species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Micromenetus dilatatus							
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	rare	B.T. Watson
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	rare	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	uncommon	B.T. Watson, A.E. Bogan
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR1201(T)	uncommon	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	patchy uncommon	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	patchy rare	B.T. Watson
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	uncommon	B.T. Watson
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
***Physella* sp.**							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	patchy uncommon	B.T. Watson
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	rare	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	rare	B.T. Watson
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	uncommon	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	patchy uncommon	B.T. Watson
000719.6btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1110	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	uncommon	B.T. Watson
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	patchy rare	B.T. Watson
000720.4btw	7/20/2000	Pasquotank	Tyrrell	Swampy trib near Second Creek	NC 94	uncommon	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	present	B.T. Watson
Planorbella duryi							
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	uncommon	B.T. Watson
Planorbella trivolvis							
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson

Table 3d (cont.). Aquatic snail species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Planorbula armigera							
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	rare	B.T. Watson
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR1201(T)	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
Promenetus exacuous							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	rare	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	present	B.T. Watson
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	rare	B.T. Watson
Pseudosuccinea columella							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	patchy uncommon	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	patchy uncommon	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	uncommon	B.T. Watson
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR1201(T)	rare	B.T. Watson
000719.6btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1110	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	patchy common	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	rare	B.T. Watson
000720.4btw	7/20/2000	Pasquotank	Tyrrell	Swampy trib near Second Creek	NC 94	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	patchy common	B.T. Watson
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	present	B.T. Watson

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CRAYFISHES

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Introduction

Crayfish play important roles in aquatic and sometimes terrestrial ecosystems, both as food sources for many animals and as consumers of plant and animal material. Despite the magnitude of their ecological roles, we have much to learn about crayfish distributions, life histories, and taxonomy. As part of the inventory of aquatic animals associated with the state-owned Bachelor Bay and Lantern Acres game lands, we conducted field surveys of the crayfishes found in waterways occurring in and around the game lands to contribute to our understanding of the distribution and status of crayfishes in North Carolina.

Reproduction and Life History

The crayfishes that occur in North Carolina (all members of the family Cambaridae) live for 2-3 years, on average (Hobbs III 1991, Taylor et al. 1996). Energy obtained from food consumption is allocated largely toward growth as juveniles and toward reproduction as adults (DiStefano 1993). Growth is accomplished through a series of exoskeletal molts (a process known as ecdysis), numbering from 5-10 until adulthood is reached, followed by only 1 (females) or 2 (males) molts per year on average throughout adulthood (Hobbs III 1991, DiStefano 1993). Male cambarid crayfishes exhibit cyclic dimorphism, alternating between a reproductively active form (form I) and a non-reproductive form (form II). Form I males can be present all year, but are usually most abundant during the fall and/or spring. Females carry fertilized eggs attached to their abdomens (a condition that is termed "in berry") for 2-20 weeks, depending on water temperatures. Once hatched, the juveniles are carried on the female until they molt into the 3rd instar (on average), after which they are free-living. Cambarid crayfishes breed more than once during their lives (Hobbs III 1991, DiStefano 1993).

Habitat Requirements and Preferences

Crayfish occur in lentic (e.g., lakes, ponds, marshes, ditches, backwaters of large rivers, groundwater) and lotic (e.g., streams, rivers, groundwater) aquatic habitats ranging from oligotrophic to hypereutrophic (Hobbs III 1991). Crayfish can be further classified as hypogean (below-ground dwellers) or epigean (above-ground dwellers). Hypogean crayfish spend much of their time in elaborate underground burrows associated with groundwater. These burrows can be in close proximity to a water body or stream, but can also be situated far from open water. Depending on the amount of time spent underground and the extent of tunnels created, burrowing crayfish are classified as primary, secondary, or tertiary burrowers (Hobbs III 1991). Generally, epigean crayfish occur in shallow (1-2 m) water, but can occur in deeper water, especially as adults. Juveniles are often found in littoral areas, where adequate shelter provides protection from predation and may mediate competition with adults. Crayfish actively forage at night, but seek shelter from predators during daylight in aquatic macrophytes, leaf litter, woody debris, overhanging roots, cobble or large boulders, burrows or depressions, and in human debris (e.g., cans, tires) (Lodge and Hill 1994).

Crayfish are affected by both water and habitat quality. Changes in water quality that interfere with respiration (e.g., drastic temperature changes, acidification, pollution) can be detrimental to crayfish populations. Many crayfish are oxygen regulators and can survive changes in oxygen levels (Reiber 1995), but some are oxygen conformers and are less likely to successfully contend with these changes (Hobbs III 1991). Water pollution, caused by sources such as sewage, agricultural and urban runoff, acidification, and auto exhaust, can result in bioaccumulation of pesticides and trace heavy metals (e.g., lead, copper, cadmium). This can harm animals that consume crayfish in addition to directly causing negative effects on crayfish (e.g., mutation, reproductive failure, death) (Taylor et al. 1995, Daveikis and Alikhan 1996, Anderson et al. 1997, Zaranko et al. 1997). Habitat destruction can also negatively affect crayfish populations. Land use practices (e.g., agriculture, logging, and development) can alter habitat resulting in fewer areas available as shelter to crayfish (Smith et al. 1996, Richter et al. 1997). For example, siltation and runoff can decrease macrophyte (a source of food and shelter) availability, and channelization can alter stream bed sculpture.

Ecological Interactions

Crayfish are both directly and indirectly linked to the ecosystems in which they live. Because they are omnivorous (i.e., consume both plant and animal food, living or dead), and because they are consumed by animals from various trophic levels, crayfish form multiple links in aquatic and terrestrial food webs (Lodge et al. 1994, Charlebois and Lamberti 1996, Nystrom et al. 1996). Thus, crayfish are involved in the transfer of large amounts of energy in these systems. Crayfish process nutrients and make them available to other animals by (1) breaking down large material via shredding into smaller sizes, and (2) converting nutrients into biomass. Crayfish feed on aquatic vegetation (e.g., macrophytes, algae, periphyton), macroinvertebrates (e.g., aquatic insects, mollusks, small crustaceans), and small vertebrates (e.g., amphibians, small/juvenile fish). Crayfish also consume nonliving organic matter such as leaf litter or terrestrial animal carcasses from the riparian zone or shore and decaying aquatic plant and animal matter (Lodge and Hill 1994). Crayfish in turn are consumed by invertebrates (including other crayfish), fish, amphibians, reptiles, birds, and mammals (Lodge and Hill 1994). Crayfish perform an important role as a member of symbiosis with many invertebrates and as host to various aquatic parasites (Lodge and Hill 1994). Crayfish also experience competition, both between species and among different sizes of individuals within a population (Lodge and Hill 1994).

The introduction of non-indigenous crayfishes to areas currently occupied by native crayfishes can result in competition or even extirpation of natives and can have impacts on other components of the ecosystem (Charlebois and Lamberti 1996, Perry 1998). For example, if crayfish become too abundant, they can be destructive to aquatic ecosystems by destroying more macrophytes than they consume, resulting in less habitat and food for other animals (Lodge et al. 1994, Nystrom et al. 1996). In fact, Lodge et al. (2000) consider nonindigenous crayfish introductions to be the single greatest threat to native crayfish biodiversity worldwide.

Taxonomy, Distribution, and Statuses

In the United States and Canada, approximately 350 taxa of crayfish are recognized (Taylor et al. 1996, J.E. Cooper, NC State Museum of Natural Sciences, Curator of Crustaceans, pers. comm.). However, many species still await description (J.E. Cooper, NCSM, pers. comm.). For example, several current species are now recognized to be species complexes consisting of more than a single taxon. Conversely, animals grouped into several species or subspecies by different authors may

actually belong to the same species. The greatest diversity of crayfishes occurs in the Southeast (Hobbs III 1991, Taylor et al. 1996), and North Carolina harbors at least 33 native (possibly up to 46) and 3 introduced species of *Cambarus, Procambarus, Orconectes,* and *Fallicambarus* (Cooper and Braswell 1995, J.E. Cooper, NCSM, pers. comm.). About half of the described crayfishes in North Carolina are of undetermined conservation status due to a lack of data on the distribution and abundance of these animals. Additionally, there are perhaps as many as a dozen native species yet to be described (J.E. Cooper, NCSM, pers. comm.). Of those species for which we have at least some information, the North Carolina Natural Heritage Program lists 10 species as significantly rare (LeGrand and Hall 1998), and the Scientific Council on Freshwater and Terrestrial Crustaceans proposes that 8 of North Carolina's species be of special concern, and that 13 species be put on a watch list (Clamp 1999). New information about current distributions has recently been reported (Cooper and Braswell 1995, Cooper et al. 1998). However, given that undescribed species exist and that we have much to learn about the distributions of crayfishes in North Carolina, it is imperative that we continue to improve our knowledge of crayfish by contributing to the growing database.

Methods

The crayfish survey of Bachelor Bay Game Land and Lantern Acres Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points, and the Roanoke and Middle rivers were surveyed via motorboat. Since most waterways were swamps, canals, or ditches, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Crayfishes were collected using a number of different techniques, depending on the conditions of the waterway being sampled (e.g., substrate type, depth of water). We collected crayfishes by hand or with dip nets from the substrate in which they were hiding (e.g., detritus, leaf packs, root wads, or under rocks). When conditions allowed visual location of crayfish, we corralled individuals into dip nets. We also collected crayfishes by electrofishing or trapping (minnow traps set overnight). Electrofishing and trapping generally proved to be a less successful method than visual location and dip netting. We dug burrows in Bachelor Bay Game Land. Digging yielded crayfish about half the time. Collected specimens were preserved and stored in 70% ethanol.

Successful identification of many cambarid crayfishes usually requires collection of reproductive (form I) males. Certain features of their gonopods – the first pair of abdominal appendages, or pleopods – can be important in their taxonomy. Form I males can be distinguished from form II males by the advanced development of the terminal elements at the tips of their gonopods. In addition, form I males have highly developed hooks on the ischia of certain walking legs (pereiopods) that are used to hold the female during copulation. The size and shape of their chelae may also vary at this stage. Some common characteristics used in identification of non-form I males are carapace length and depth/width ratio, areola width and length, presence and placement of spines, rostrum shape, color, and chela characteristics. Crayfishes were identified by using a taxonomic key (Hobbs Jr. 1991) and a checklist (Hobbs Jr. 1989), by comparing individuals to reference collection specimens (North Carolina Wildlife Resources Commission, and North Carolina State Museum of Natural Sciences), and via personal communication with Dr. J.E. Cooper.

Common names are according to Clamp (1999). As our understanding of crayfish taxonomy continues to improve, the identifications of the species we collected may change.

In addition to identifying individuals, we noted approximate abundances of each type of crayfish collected, and quantified average carapace lengths of those collected (from the tip of the rostrum to the posterior carapace edge). We also looked for evidence of recent reproduction and estimated habitat preferences of each species based on the areas from which they were collected. We recorded presence/absence data for each species encountered at each site visited to allow a crude estimate of the distribution of each species within the waterways associated with the game lands. These data will also be added to a larger database describing statewide distributions. Where possible, we recorded notes on ecological interactions (e.g., abundance of food, presence of competitors or predators, quality of habitat). For logistical and ethical reasons, we did not preserve every crayfish collected.

For crayfishes, a survey effectiveness score (SES) was determined at each site (if possible) and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Bachelor Bay Game Land

Over 8 days from 13 June to 17 August 2000, 28 sites were inventoried. Crayfish were collected or observed at 21 sites (Figure 4a and Table 4a). No crayfish were observed at 7 sites, burrows only were observed at 1 site, and an unidentified carapace and a potential burrow were observed at 1 site. Five species of crayfish were collected during the survey period: *Cambarus (Lacunicambarus) diogenes* Girard, 1852, *Fallicambarus (Creaserinus) fodiens* (Cottle, 1863), *Orconectes (Crockerinus) virginiensis* Hobbs, 1951, *Procambarus (Ortmannicus) acutus* (Girard, 1852), and *Procambarus (Scapulicambarus) clarkii* (Girard, 1852), a nonindigenous species. *Palaemonetes paludosus* (freshwater shrimp) was also collected during this survey. See Table 4b for statistics on carapace lengths of each species of crayfish collected. For common species, these calculations were performed on a sample only; we did not record measurements for every individual collected. The SES for crayfishes was 2.93.

Cambarus (L.) diogenes (devil crayfish) was observed at 4 sites. At 3 sites, several juveniles only were collected from detritus along edges or dug from burrows. At the fourth site, only a form I male carapace was collected. Because this species is a primary burrower, it is likely that it is more common than our survey indicates. We noted the presence of burrows with chimneys at 1 site where *F. fodiens* was found and at 2 sites where no crayfish were collected. Digging chimney burrows yielded only *C. diogenes*, but other burrows may have contained *F. fodiens*. The carapace coloration was mostly slate blue-brown in color, legs and undersides were pale blue, and all sutures and chelae edges were bright red. This species is considered stable and is found throughout much of the eastern Piedmont and Coastal Plain of this and other states.

Fallicambarus (C.) fodiens (no common name available) was found at only 2 sites, and was rare at both. However, this species is a primary burrower, so it is likely that it is more common than our survey indicated. We noted the presence of burrows with chimneys at 1 site where *F. fodiens* was

found and at 2 sites where no crayfish were collected. Digging chimney burrows yielded only *C. diogenes*, but other burrows may have contained *F. fodiens*. The presence of juveniles indicated that reproduction had recently occurred. Animals were collected from vegetation in shallow areas. These animals were brown in color, with speckling on the carapace. This species is considered stable and is found throughout much of the eastern Piedmont and Coastal Plain of this and other states.

Orconectes (C.) virginiensis (Chowanoke crayfish) occurred at only 2 sites. Two form II males were collected from under wood in open water or from detritus along shore in Middle River. One form II male was collected along an undercut bank in the lower Roanoke River, just before its confluence with the Albemarle Sound. The individuals collected were relatively small for the genus *Orconectes*. Carapace coloration was an olive-tan with brown and black markings, including a distinct trapezoidal saddle pattern. Chelae were tipped in orange and highlights were orangeish as well. This species is proposed by the Scientific Council of Freshwater and Terrestrial Crustaceans to be listed as state special concern (Clamp 1999).

Procambarus (O.) acutus (White River crayfish) occurred at about two-thirds of the sites surveyed. Across most sites, the abundance of this species ranged from rare to common. Reproduction was currently ongoing, as juveniles were collected from many sites. Animals were collected from various types of habitat, but most often from detritus or vegetation in areas with slow flow. This species is one of the largest *Procambarus* species occurring in North Carolina. Its coloration varies across its range. Generally, carapace color consists of different shades of tan, brown, and rust, but can also be olive green. Adornment includes dark speckling, cream mottling, and blurred stripes along carapace sides, and a wide dark stripe on the dorsal abdomen. This species is considered stable and is found throughout much of the Piedmont and Coastal Plain of this and other states.

Procambarus (S.) clarkii (red swamp crayfish) was present at 1 site, and no other species of crayfish was found there. No live animals were observed, but 1 juvenile female carapace and numerous burrows were observed. This species is one of the largest *Procambarus* species occurring in North Carolina, and is similar in size to *P. acutus*. Generally, carapace color consists of different shades of tan, brown, and red-brown, with speckling or mottling. Often, the carapace and chelae appear bumpy, and chelae of adults usually bear bright red bumps and red edges. This species can be differentiated from *P. acutus* by its linear areola. This species is a nonindigenous species, and wild populations have been documented in many parts of the state (Cooper et al. 1998, Fullerton and Watson 2001).

Palaemonetes paludosus (freshwater shrimp) was collected from 9 sites. Animals were usually collected from vegetation along banks.

Lantern Acres Game Land

Over 3 days from 18 to 20 July 2000, 19 sites were inventoried. Crayfish were collected or observed at 17 sites (Figure 4b and Table 4c). No crayfish were observed at 1 site, and burrows only were observed at 1 site. Two species of crayfish were collected during the survey period: *Procambarus (Ortmannicus) acutus* (Girard, 1852) and *Procambarus (Scapulicambarus) clarkii* (Girard, 1852), a nonindigenous species. *Palaemonetes paludosus* (freshwater shrimp) was also collected during this survey. See Table 4d for statistics on carapace lengths of each species of crayfish collected. These calculations were performed on a sample only; we did not record measurements for every individual collected. The SES for crayfishes was 2.63.

Procambarus (O.) acutus (White River crayfish) occurred at about half of the sites surveyed. Across most sites, the abundance of this species ranged from rare to common. Reproduction was ongoing, as most animals collected were juveniles. This species was collected from various types of habitat, but most often from detritus or vegetation in areas with slow flow. This species is one of the largest *Procambarus* species occurring in North Carolina. Its coloration varies across its range. Generally, carapace color consists of different shades of tan, brown, and rust, but can also be olive green. Adornment includes dark speckling, cream mottling, and blurred stripes along carapace sides, and a wide dark stripe on the dorsal abdomen. This species is considered stable and is found throughout much of the Piedmont and Coastal Plain of this and other states.

Procambarus (S.) clarkii (red swamp crayfish) occurred at 6 sites. Abundance ranged from rare to abundant. Juveniles were present at 4 sites, indicating that reproduction has recently occurred. This species was collected from vegetation, woody debris and detritus along stream banks. This species is one of the largest *Procambarus* species occurring in North Carolina, and is similar in size to *P. acutus*. Generally, carapace color consists of different shades of tan, brown, and red-brown, with speckling or mottling. Often, the carapace and chelae appear bumpy, and chelae of adults usually bear bright red bumps and red edges. This species can be differentiated from *P. acutus* by its linear areola. This species is a nonindigenous species, and wild populations have been documented in many parts of the state (Cooper et al. 1998, Fullerton and Watson 2001).

We noted the presence of chimneyless burrows at 2 sites and chimney burrows at 1 site where *P. clarkii* was present, and at 1 site where no crayfish were collected but which possibly had old burrow remnants.

Palaemonetes paludosus (freshwater shrimp) was collected from 8 sites. Animals were usually found in vegetation along banks.

Discussion

The overall diversity of crayfishes in this system was fair, likely because the survey area encompassed portions of two river basins. In the Roanoke River Basin, where approximately one-third of our survey efforts were focused, 4 species were collected. Based on our survey and given our limitation of finding burrowing species, *Cambarus diogenes, F. fodiens,* and *O. virginiensis* were not well distributed, occurring at only 1-2 sites each, and were rare at these sites. *Procambarus acutus* was well distributed throughout the portion of our survey that occurred in the Roanoke River Basin, and was generally uncommon. In the Pasquotank River Basin, where the majority of our survey efforts were focused, 3 species were collected. *Fallicambarus fodiens* occurred at only 1 site and was rare there. *Procambarus acutus* and *P. clarkii* were more widely distributed, with *P. acutus* occurring at greater than half of surveyed sites, and *P. clarkii* occurring at 7 sites. These species ranged in abundance from rare to abundant, but were generally common. In both river basins, each species occurred only with *P. acutus* except *P. clarkii*, which occurred alone at all sites from which it was collected.

Aspects of crayfish communities can tell us something about the system in which they occur. Although we did not directly test water quality, it was clear that the conditions in Bachelor Bay and Lantern Acres game lands were favorable to support crayfish (at least these species) in most of the waterways sampled. Current reproduction was evident for all but *O. virginiensis*. Only 3 form II males of this species were collected, so we cannot establish whether reproduction was occurring.

Potential food sources (e.g., allochthonous and autochthonous organic debris, aquatic insects) were available, and vegetation was present. Crayfishes were rarely seen away from cover. Predation pressure on these crayfishes (especially juveniles) was likely fair because the fish community in this system was fairly healthy (see *Fish* section of this report). However, plenty of cover-providing habitat was available to crayfishes and likely lessened direct impact by predation. It is unclear whether any of the less widespread species was limited by competition or by abiotic factors such as low dissolved oxygen or high acidity.

Procambarus clarkii, an introduced species, has been collected from numerous river basins in North Carolina (Cooper et al. 1998, Fullerton and Watson 2001). This species is the primary type of crayfish consumed by humans, and is raised in aquaculture facilities around the state. The wild population in this area may be a result of escapement from an aquaculture facility(ies) (especially during the floods following hurricanes). Alternatively, because the Scuppernong River and its tributaries are popular fishing locations, *P. clarkii* may have been released after being used as fishing bait. It is unclear whether this species has had any deleterious effects on native crayfishes in this area because this has not been adequately studied. It appears to be a primarily lentic crayfish, and will likely threaten mainly other species that prefer lentic conditions.

During our survey, we found 4 of the 6+ species historically known to occur in the Roanoke River Basin, and 2 of the 3 native species known to occur in the Pasquotank River Basin. In addition, we found 1 nonindigenous species not previously known to occur there. Two species that we did not find, but that occur in Roanoke River Basin, are *Cambarus (H.) longulus* Girard, 1852 and *C. (P.)* sp. C (a species complex related to *C. (P.) acuminatus* Faxon, 1884). These species are known to occur farther upstream and are not likely to occur as far down in the drainage basin as the areas we surveyed. *Cambarus diogenes* is known to occur in the Pasquotank River Basin, but we did not collect any specimens from that river basin during this survey. Although it is believed that *Cambarus (P.)* sp. C may also occur in the Pasquotank River Basin, we did not find any specimens of this species. Given survey effectiveness scores of nearly 3.0 for both game lands, it is reasonable to assume that our survey efforts were relatively sufficient to have captured an accurate reflection of the crayfishes present in the area.

This survey has helped to further clarify distribution boundaries of several species in the Roanoke and Pasquotank river basins, to establish the continued presence of a rare species in the Roanoke River Basin (*Orconectes virginiensis*), and has alerted us to the presence of a nonindigenous species in the Pasquotank River Basin.

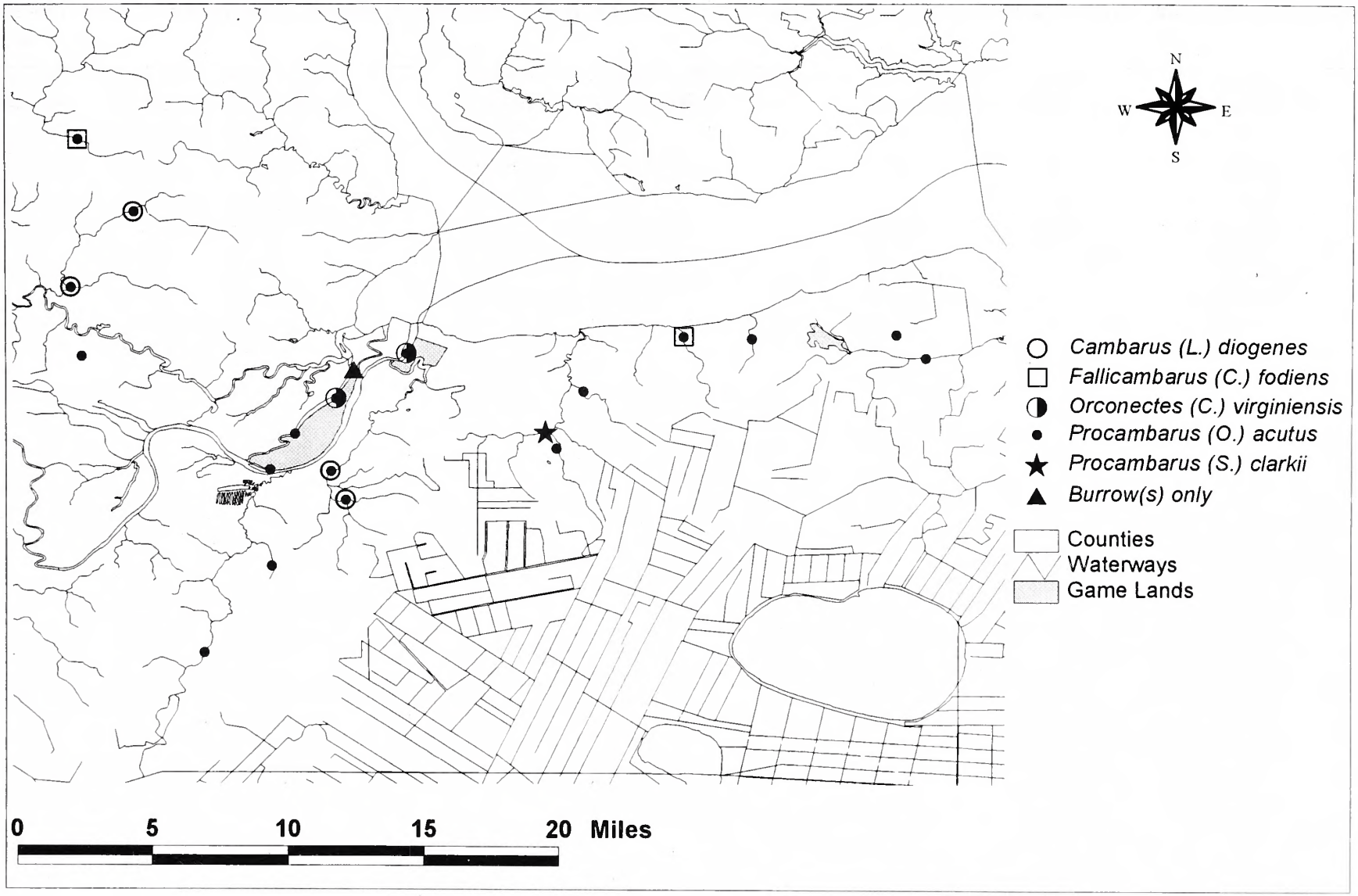

Figure 4a. Map of sites indicating where each species of crayfish was collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

Table 4a. Crustaceans (crayfishes and shrimps) found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Cambarus (Lacunicambarus) diogenes							
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	uncommon	A.H. Fullerton
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	A.H. Fullerton
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	present	A.H. Fullerton
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	present	A.H. Fullerton
Fallicambarus (Creaserinus) fodiens							
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Creek	SR 1001 -	present	A.H. Fullerton
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	present	A.H. Fullerton
Orconectes (Crockerinus) virginiensis							
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	A.H. Fullerton
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	A.H. Fullerton
Procambarus (Ortmannicus) acutus							
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	common	A.H. Fullerton
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	A.H. Fullerton
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	A.H. Fullerton
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Creek	SR 1001 -	present	A.H. Fullerton
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	present	A.H. Fullerton
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	present	A.H. Fullerton
000622.4btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1302 -	rare	A.H. Fullerton
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	rare	A.H. Fullerton
000808.1btw	8/8/2000	Roanoke	Martin/Washngtn	Welch Creek	SR 1103/1152 -/+	rare	A.H. Fullerton
000808.2btw	8/8/2000	Roanoke	Washington	Tributary to Welch Creek	Bike 3/SR 1100 -	present	A.H. Fullerton
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	uncommon	A.H. Fullerton
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	A.H. Fullerton
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	A.H. Fullerton
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	A.H. Fullerton
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	A.H. Fullerton
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	patchy common	A.H. Fullerton
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	rare	A.H. Fullerton
000817.3btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Ck (Mill Ck?)	US 64/NC 32/Bike 3+	present	A.H. Fullerton

Table 4a (cont.). Crustaceans (crayfishes and shrimps) found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Procambarus (Scapulicambarus) clarkii							
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	A.H. Fullerton
Crayfish (carapace and potential burrow)							
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	present	A.H. Fullerton
Burrow(s) only							
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	A.H. Fullerton
Palaemonetes paludosus							
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	present	A.H. Fullerton
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	common	A.H. Fullerton
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	present	A.H. Fullerton
000808.1btw	8/8/2000	Roanoke	Martin/Washngtn	Welch Creek	SR 1103/1152 -/+	patchy uncommon	A.H. Fullerton
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	present	A.H. Fullerton
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	A.H. Fullerton
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	common	A.H. Fullerton
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	patchy common	A.H. Fullerton
000817.3btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Ck (Mill Ck?)	US 64/NC 32/Bike 3+	present	A.H. Fullerton

Table 4b. Statistics on carapace lengths (mm) of crayfishes found in Bachelor Bay Game Land and associated waterways. See text for common names.

	Avg	Std	Min	Max
Cambarus (Lacunicambarus) diogenes				
male I (1 record)	31.5		31.5	31.5
Species Total (1 record)	31.5		31.5	31.5
Fallicambarus (Creaserinus) fodiens				
male II (1 record)	18.5		18.5	18.5
Species Total (1 record)	18.5		18.5	18.5
Orconectes (Crockerinus) virginiensis				
male II (1 record)	17.0		17.0	17.0
Species Total (1 record)	17.0		17.0	17.0
Procambarus (Ortmannicus) acutus				
female (2 records)	13.5	0.7	13.0	14.0
male II (2 records)	20.3	3.9	17.5	23.0
Species Total (4 records)	16.9	4.5	13.0	23.0

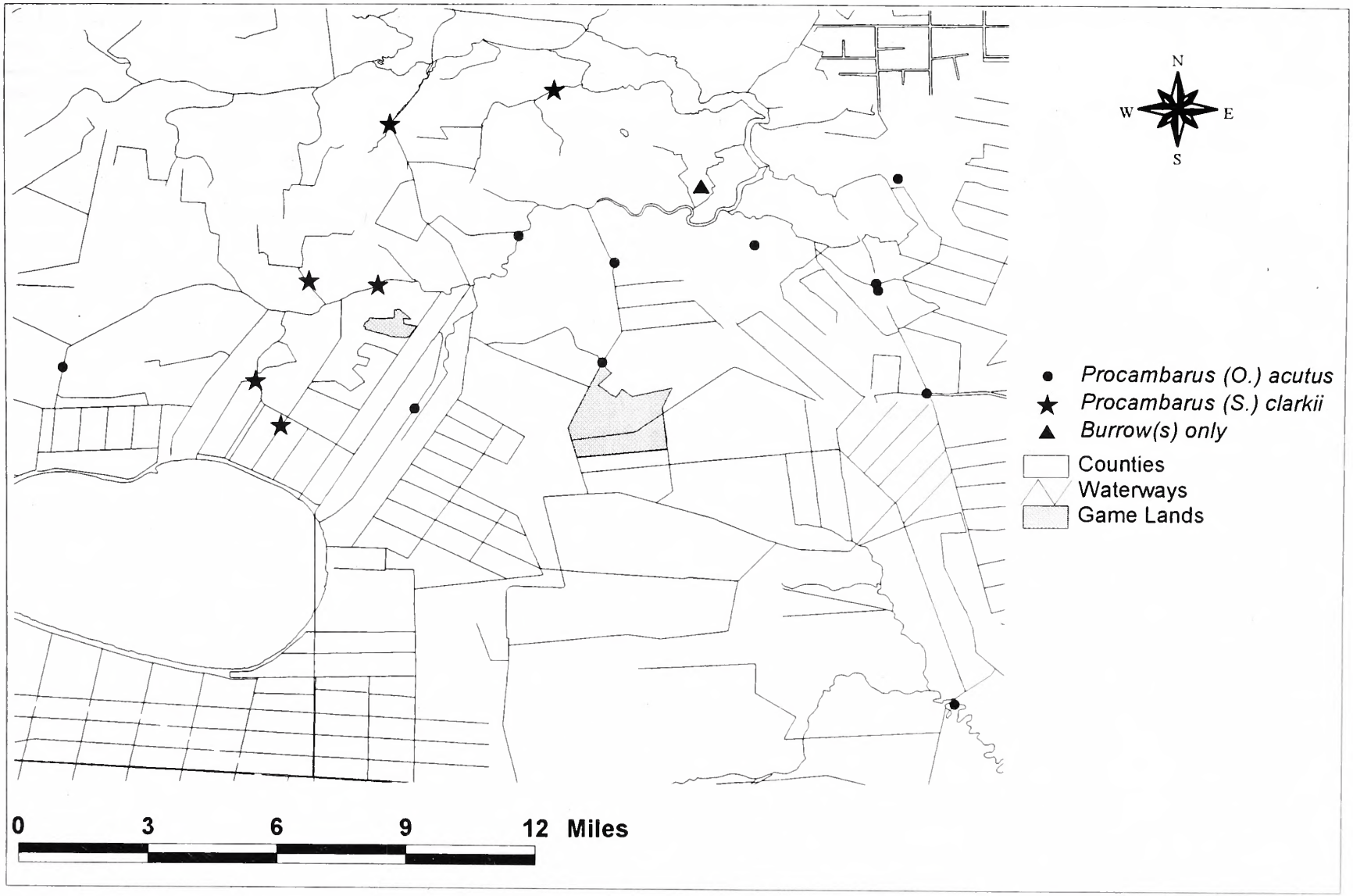

Figure 4b. Map of sites indicating where each species of crayfish was collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

Table 4c. Crustaceans (crayfishes and shrimps) found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Procambarus (Ortmannicus) acutus							
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	uncommon	A.H. Fullerton
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	rare	A.H. Fullerton
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	A.H. Fullerton
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	rare	A.H. Fullerton
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	rare	A.H. Fullerton
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	uncommon	A.H. Fullerton
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	common	A.H. Fullerton
000720.4btw	7/20/2000	Pasquotank	Tyrrell	Swampy trib near Second Creek	NC 94	common	A.H. Fullerton
000720.5btw	7/20/2000	Pasquotank	Tyrrell	Canal trib to Riders Creek	SR 1301 ca SR 1303	uncommon	A.H. Fullerton
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	A.H. Fullerton
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	present	A.H. Fullerton
Procambarus (Scapulicambarus) clarkii							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	common	A.H. Fullerton
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	abundant	A.H. Fullerton
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	present	A.H. Fullerton
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	rare	A.H. Fullerton
000719.4btw	7/19/2000	Pasquotank	Washngtn/Tyrrell	Bunton Creek	SR 1308/SR 1201	present	A.H. Fullerton
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong R @ Bull Bay	SR 1200+	uncommon	A.H. Fullerton
Burrow(s) only							
000719.6btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1110		A.H. Fullerton
Palaemonetes paludosus							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	rare	A.H. Fullerton
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	uncommon	A.H. Fullerton
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	uncommon	A.H. Fullerton
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	uncommon	A.H. Fullerton
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	rare	A.H. Fullerton
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	uncommon	A.H. Fullerton
000720.5btw	7/20/2000	Pasquotank	Tyrrell	Canal trib to Riders Creek	SR 1301 ca SR 1303	present	A.H. Fullerton
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	present	A.H. Fullerton

Table 4d. Statistics on carapace lengths (mm) of crayfishes found in Lantern Acres Game Land and associated waterways. See text for common names.

	Avg	Std	Min	Max
Procambarus (Ortmannicus) acutus				
female (3 records)	6.8	2.0	5.0	9.0
Species Total (3 records)	6.8	2.0	5.0	9.0
Procambarus (Scapulicambarus) clarkii	Avg	Std	Min	Max
exoskeleton (1 record)	22.0		22.0	22.0
female (22 records)	14.4	7.2	8.0	38.5
male II (11 records)	13.0	5.6	7.5	26.5
Species Total (34 records)	14.1	6.7	7.5	38.5

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FRESHWATER FISHES

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Introduction

Fishes are the most numerous and diverse of the major vertebrate groups. Their various morphological, behavioral, reproductive, and physiological adaptations have allowed them to dominate the waters of the world. Fishes can be found in a broad array of habitats, including vernal pools, mountain streams, and the ocean floor. Their dominance is reflected in the number of living species. Over 24,600 species have been described (Moyle and Cech 1996), and it is believed that this number may increase to approximately 28,500 (Nelson 1994). The North American continent harbors approximately 1,100 species of freshwater fish (Burr and Mayden 1992), with 790 (75%) species occurring in the United States (Page and Burr 1991). Nearly 200 native species can be found in North Carolina (Menhinick 1991).

While most of the attention from the public and fisheries biologists is directed towards the game fishes, these species make up only about 5% of the freshwater fish fauna in the United States. The remaining 95% are little known, but charismatic, nongame species, such as darters and minnows. Nongame fishes play a vital role in the balance of aquatic ecosystems. Their diets are diverse, and, in turn, they serve as dietary components for sport fishes, water birds, and other wildlife. They also are important indicators of water quality and can signal when aquatic ecosystems are being negatively impacted. Game fishes also are important components of aquatic ecosystems and provide a source of recreation and employment for many people. Unfortunately, in 1989, the American Fisheries Society regarded 364 North American freshwater fish species as endangered, threatened, or special concern, an increase of 45% in just 10 years (Williams et al. 1989). This number represents approximately one-third of the North American native freshwater fish fauna. Likewise, the southern United States, which supports more native fishes than any comparable size on the North American continent north of Mexico, has experienced a 75% increase in jeopardized fishes since 1989 and a 125% increase in 20 years (Warren et al. 2000). In North Carolina, approximately 25% of the freshwater fishes are state listed. Some of the reasons for this decline include habitat alteration and loss, chemical pollution, overexploitation, and introduction of exotic species. Given this information, it is essential that we better understand the taxonomy, distribution, and conservation needs of the various taxa. Therefore, a fish inventory of the waterways in and around the state-owned Bachelor Bay Game Land and Lantern Acres Game Land was initiated to ascertain some of this needed information.

Methods

The freshwater fish survey of Bachelor Bay Game Land and Lantern Acres Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points,

and the Roanoke and Middle rivers were surveyed via motorboat. Since most waterways were swamps, canals, or ditches, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Freshwater fishes were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common method used was dip netting. This method was predominantly used because most of the waterways we encountered had high conductivities making them difficult to electrofish. We typically use electrofishing as our primary survey technique due to its advantages regarding efficiency and effectiveness, but only 5 sites between the 2 game lands were sampled in this manner. Given the conditions of the waterways we encountered, the use of minnow traps also was implemented to help augment the accuracy of our surveys. Most fishes collected were identified to species and released unharmed. However, it was necessary to perform some of the identifications in the laboratory. These identifications were carried out by fixing the fish in 10% formalin and preserving them in 70% ethanol. Once the fishes were preserved, they were identified with the use of a compound microscope (Nikon). Fishes were identified according to Menhinick (1991), Page and Burr (1991), Rhode et al. (1994), and Jenkins and Burkhead (1994). Dr. Wayne C. Starnes and others (G.M. Hogue, T.L. Fullbright, and Dr. M.E. Raley) from the NC State Museum of Natural Sciences verified some of the identifications. Besides presence-absence data, relative abundance and recent reproduction information were noted for each species to determine population health.

For fishes, a survey effectiveness score (SES) was determined at each site (if possible), and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Bachelor Bay Game Land

Over 8 days from 13 June to 17 August 2000, 28 sites were inventoried and fish were collected or observed at all 28 sites (Figure 5a). Twenty-eight species representing 14 families were documented during the survey of Bachelor Bay Game Land (Tables 5a and 5b). Of the 49 species of freshwater fish species that have been documented in the Bertie and Washington county portions of the Roanoke and Pasquotank river basins (Menhinick 1991), we confirmed the presence of only 25 of these species. Limitations as to our sampling techniques, and access of all available habitats and sampling range within the counties were the most likely reasons for the absence of particular species. We did document the presence of 3 species that were not previously documented from the Washington and Bertie county portions of the Roanoke River Basin: *Fundulus lineolatus* (lined topminnow), *Notropis altipinnis* (highfin shiner), and *N. hudsonius* (spottail shiner). Overall, abundance, distribution, and recent reproduction were difficult to determine for most fish species given that our SES was 2.36. This score would have

been significantly lower if we would have assigned scores of 1.0 to the Middle River and Roanoke River sites rather than not designating scores.

Lantern Acres Game Land

Over 3 days from 18 July to 20 July 2000, 19 sites were inventoried and freshwater fish were collected or observed at all 19 localities (Figure 5b). Twenty-one species representing 12 families were documented during the survey of Lantern Acres Game Land (Tables 5c and 5d). Of the 60 species of freshwater fish species that have been documented in the Washington and Tyrrell county portions of the Pasquotank River Basin (Menhinick 1991), we confirmed the presence of only 21 of these species. Limitations as to our sampling techniques, and access of all available habitats and sampling range within the counties were the most likely reasons for the absence of particular species. We did not document the presence of any species that were not previously documented from the Washington and Tyrrell county portions of the Pasquotank River Basin. Overall, abundance, distribution, and recent reproduction were difficult to determine for most fish species given that our SES was 1.89.

Discussion

The waterways associated with Bachelor Bay Game Land and Lantern Acres Game Land contain a relatively low diversity and distribution of fish species given past records and distributions (Menhinick 1991). Overall, 33 species representing 15 families were collected between the 2 game lands. With the exception of species like *Gambusia holbrookii*, *Umbra pygmaea*, and *Enneacanthus gloriosus*, most of the species tended to occur over a restricted area. Species abundance was typically low at many sites with centrarchids usually comprising a majority of the biomass. The low distribution and abundance of a number of the species were likely significantly affected by the lack of intensive survey techniques. A number of sites had characteristics that made them virtually impossible to backpack electrofish, while even some of the sites we electrofished were difficult due to the water clarity. Therefore, dip netting became the primary, but less than desired, technique during the survey, resulting in a SES near 2 for Bachelor Bay Game Land and below 2 for Lantern Acres Game Land. Overall, the area we surveyed was mostly rural, resulting in minimal urbanization effects and some agricultural impacts, which may tend to reflect different results than those reported here. However, ditching was prominent in area around Lantern Acres Game Land. Unfortunately, we do not have any recent survey results for comparison to obtain an accurate reflection of the species composition and distribution of the area.

While no threatened or endangered fish species was collected during the survey of Bachelor Bay Game Land or Lantern Acres Game Land, continual research and status surveys are needed to determine the present status of each species. Four species were collected during the survey that were previously undocumented from the Bertie and Washington county portions of the Roanoke and Pasquotank river basins (Menhinick 1991), which is most likely due to a lack of surveys in the area. Current land management practices, including agriculture and urbanization, are having an effect on the fish fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

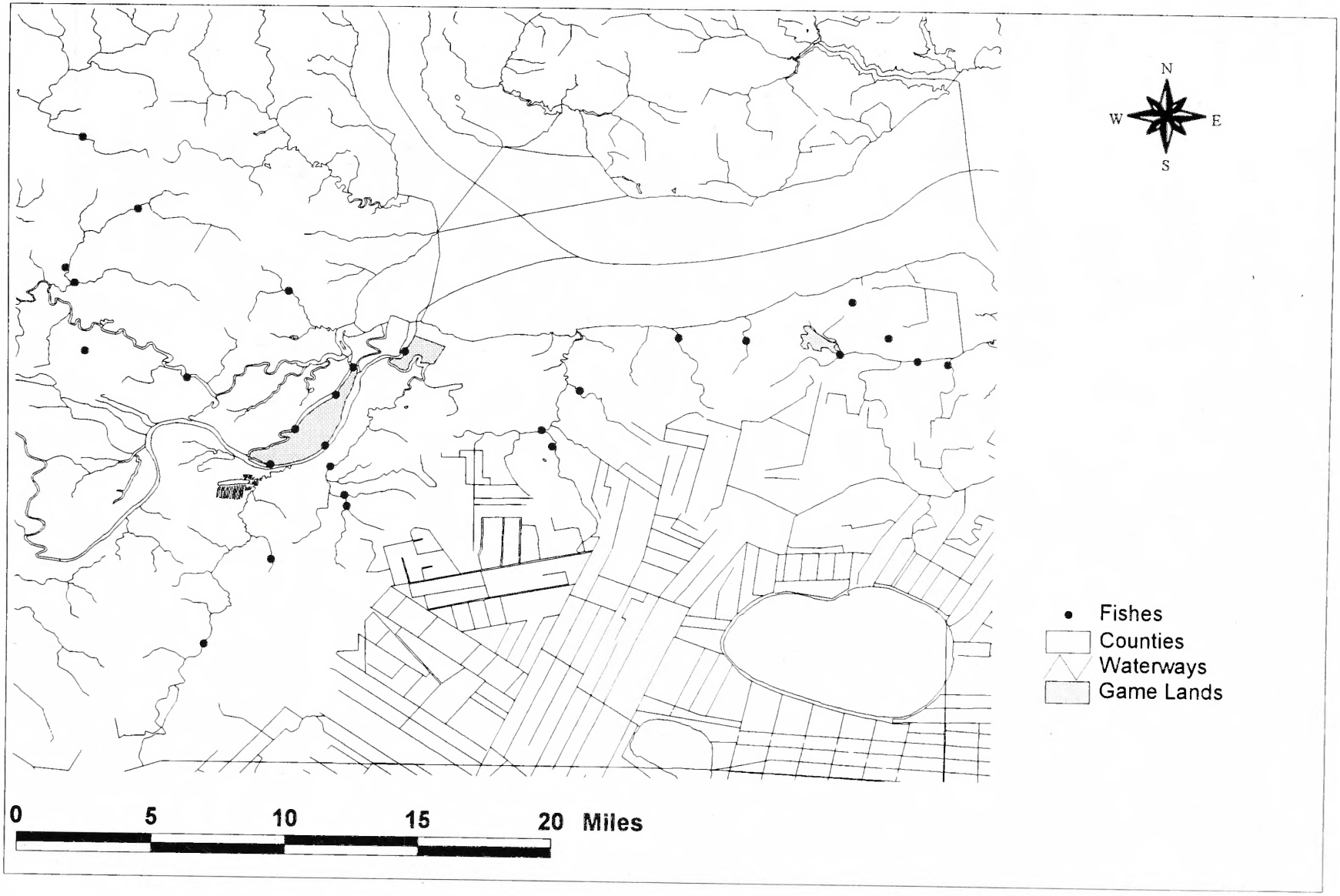

Figure 5a. Map of sites indicating where fishes were collected in the Bachelor Bay Game Land aquatic inventory, Bertie and Washington counties, North Carolina, 2000.

Table 5a. Fish species found in Bachelor Bay Game Land and associated waterways.

Anguillidae	
Anguilla rostrata	american eel
Amblyopsidae	
Chologaster cornuta	swampfish
Amiidae	
Amia calva	bowfin
Aphredoderidae	
Aphredoderus sayanus	pirate perch
Catostomidae	
Erimyzon oblongus	creek chubsucker
Centrarchidae	
Acantharchus pomotis	mud sunfish
Centrarchus macropterus	flier
Chaenobryttus gulosus	warmouth
Enneacanthus gloriosus	bluespotted sunfish
Lepomis gibbosus	pumpkinseed
Lepomis macrochirus	bluegill
Pomoxis nigromaculatus	black crappie
Cyprinidae	
Cyprinella analostana	satinfin shiner
Notemigonus crysoleucas	golden shiner
Notropis altipinnis	highfin shiner
Notropis hudsonius	spottail shiner
Cyprinodontidae	
Fundulus diaphanus	banded killifish
Fundulus lineolatus	lined topminnow
Elassomatidae	
Elassoma zonatum	banded pygmy sunfish
Esocidae	
Esox americanus	redfin pickerel
Ictaluridae	
Ameiurus natalis	yellow bullhead
Ameiurus nebulosus	brown bullhead
Noturus gyrinus	tadpole madtom

Table 5a (cont.). Fish species found in Bachelor Bay Game Land and associated waterways.

Percidae	
Etheostoma fusiforme	swamp darter
Etheostoma olmstedi	tessellated darter
Etheostoma serrifer	sawcheek darter
Poeciliidae	
Gambusia holbrookii	eastern mosquitofish
Umbridae	
Umbra pygmaea	eastern mudminnow

Table 5b. Freshwater fish species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Acantharchus pomotis							
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
Ameiurus natalis							
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	rare	B.T. Watson
Ameiurus nebulosus							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	common	B.T. Watson, W.C. Starnes
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
***Ameiurus* sp.**							
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Ck	SR 1001 -	present	B.T. Watson
Amia calva							
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	rare	B.T. Watson
Anguilla rostrata							
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	rare	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	uncommon	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	abundant	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	rare	B.T. Watson

Table 5b (cont.). Freshwater fish species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Aphredoderus sayanus							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	uncommon	B.T. Watson
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	uncommon	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	uncommon	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	uncommon	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	common	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Creek	SR 1115	present	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson
000808.2btw	8/8/2000	Roanoke	Washington	Tributary to Welch Creek	Bike 3/SR 1100 -	present	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	rare	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Trib to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	present	B.T. Watson
Centrarchus macropterus							
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	rare	B.T. Watson
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Ck	SR 1001 -	present	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	present	B.T. Watson
Chaenobryttus gulosus							
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	rare	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	W.C. Starnes
Chologaster cornuta							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	rare	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	present	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	rare	B.T. Watson
000622.4btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1302 -	present	B.T. Watson
Cyprinella analostana							
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	W.C. Starnes

Table 5b (cont.). Freshwater fish species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Elassoma zonatum							
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson
Enneacanthus gloriosus							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	rare	B.T. Watson
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	uncommon	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	common	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	present	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	uncommon	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Creek	SR 1115	present	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	rare	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	uncommon	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	present	B.T. Watson
Erimyzon oblongus							
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	patchy common	B.T. Watson, W.C. Starnes
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	present	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	uncommon	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	present	B.T. Watson
Esox americanus							
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	common	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	abundant	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	uncommon	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	present	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	uncommon	B.T. Watson
000622.4btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1302 -	present	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	uncommon	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	uncommon	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	uncommon	B.T. Watson

Table 5b (cont.). Freshwater fish species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Etheostoma fusiforme							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	uncommon	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	present	B.T. Watson
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	present	B.T. Watson, W.C. Starnes
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	uncommon	B.T. Watson
Etheostoma olmstedi							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	present	B.T. Watson, W.C. Starnes
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	present	B.T. Watson, W.C. Starnes
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.5btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Etheostoma serrifer							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	rare	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	uncommon	B.T. Watson
000808.2btw	8/8/2000	Roanoke	Washington	Tributary to Welch Creek	Bike 3/SR 1100 -	present	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	B.T. Watson
Fundulus diaphanus							
000809.1btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson, W.C. Starnes
Fundulus lineolatus							
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson

Table 5b (cont.). Freshwater fish species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Gambusia holbrookii							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	common	B.T. Watson
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	present	B.T. Watson
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	common	B.T. Watson
000621.2btw	6/21/2000	Roanoke	Bertie	Tributary to Hoggard Mill Ck	SR 1001 -	present	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	uncommon	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	present	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	uncommon	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	uncommon	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.4btw	8/9/2000	Roanoke	Bertie	Roanoke River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	uncommon	B.T. Watson
000817.2btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek	US 64/NC 32/Bike 3-	common	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	present	B.T. Watson
Lepomis gibbosus							
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Lepomis macrochirus							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	common	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	common	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	rare	B.T. Watson
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	uncommon	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
***Lepomis* sp.**							
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000817.3btw	8/17/2000	Pasquotank	Washington	Tributary to Kendrick Creek (Mill Ck?)	US 64/NC 32/Bike 3+	present	B.T. Watson
***Lepomis* spp.**							
000614.6btw	6/14/2000	Roanoke	Bertie	Cashie River	SR 1500	present	B.T. Watson

Table 5b (cont.). Freshwater fish species found in Bachelor Bay Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Notemigonus crysoleucas							
000614.5btw	6/14/2000	Roanoke	Bertie	Sutton Creek	NC 308	rare	W.C. Starnes
Notropis altipinnis							
000614.4btw	6/14/2000	Roanoke	Bertie	Wading Place Creek	NC 308	patchy uncommon	B.T. Watson
Notropis hudsonius							
000808.3btw	8/8/2000	Roanoke	Washington	Conaby Creek	NC 45	rare	B.T. Watson, W.C. Starnes
Noturus gyrinus							
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	rare	B.T. Watson
000808.4btw	8/8/2000	Pasquotank	Washington	Beaver Dam Branch	SR 1301 +	present	B.T. Watson
000809.2btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.3btw	8/9/2000	Roanoke	Bertie	Middle River	by boat	present	B.T. Watson
000809.6btw	8/9/2000	Roanoke	Washington	Roanoke River	by boat	present	B.T. Watson
Pomoxis nigromaculatus							
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	W.C. Starnes
Umbra pygmaea							
000613.1btw	6/13/2000	Roanoke	Bertie	Cashoke Creek	SR 1509-/+	common	B.T. Watson
000613.3btw	6/13/2000	Roanoke	Bertie	Wading Place Creek	SR 1504-	common	B.T. Watson
000615.2btw	6/15/2000	Roanoke	Bertie	Swamp trib to Cashie River	SR 1500+	common	B.T. Watson
000621.3btw	6/21/2000	Roanoke	Washington	Tributary(s) to Conaby Creek	NC 45 -	rare	B.T. Watson
000621.4btw	6/21/2000	Roanoke	Washington	Tributary to trib to Conaby Creek	SR 1115	present	B.T. Watson
000622.1btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1303 -/+	present	B.T. Watson
000622.2btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1308 -	common	B.T. Watson
000622.3btw	6/22/2000	Pasquotank	Washington	Deep Creek	SR 1302 +	uncommon	B.T. Watson
000622.4btw	6/22/2000	Pasquotank	Washington	Tributary to Deep Creek	SR 1302 -	present	B.T. Watson
000622.5btw	6/22/2000	Pasquotank	Washington	Big Swamp	SR 1344	common	B.T. Watson
000622.6btw	6/22/2000	Pasquotank	Washington	Tributary to Albemarle Sound	US 64	common	B.T. Watson
000808.1btw	8/8/2000	Roanoke	Martin/Washington	Welch Creek	SR 1103/1152 -/+	present	B.T. Watson
000817.1btw	8/17/2000	Pasquotank	Washington	Chapel Swamp	US 64/NC 32/Bike 3-	rare	B.T. Watson

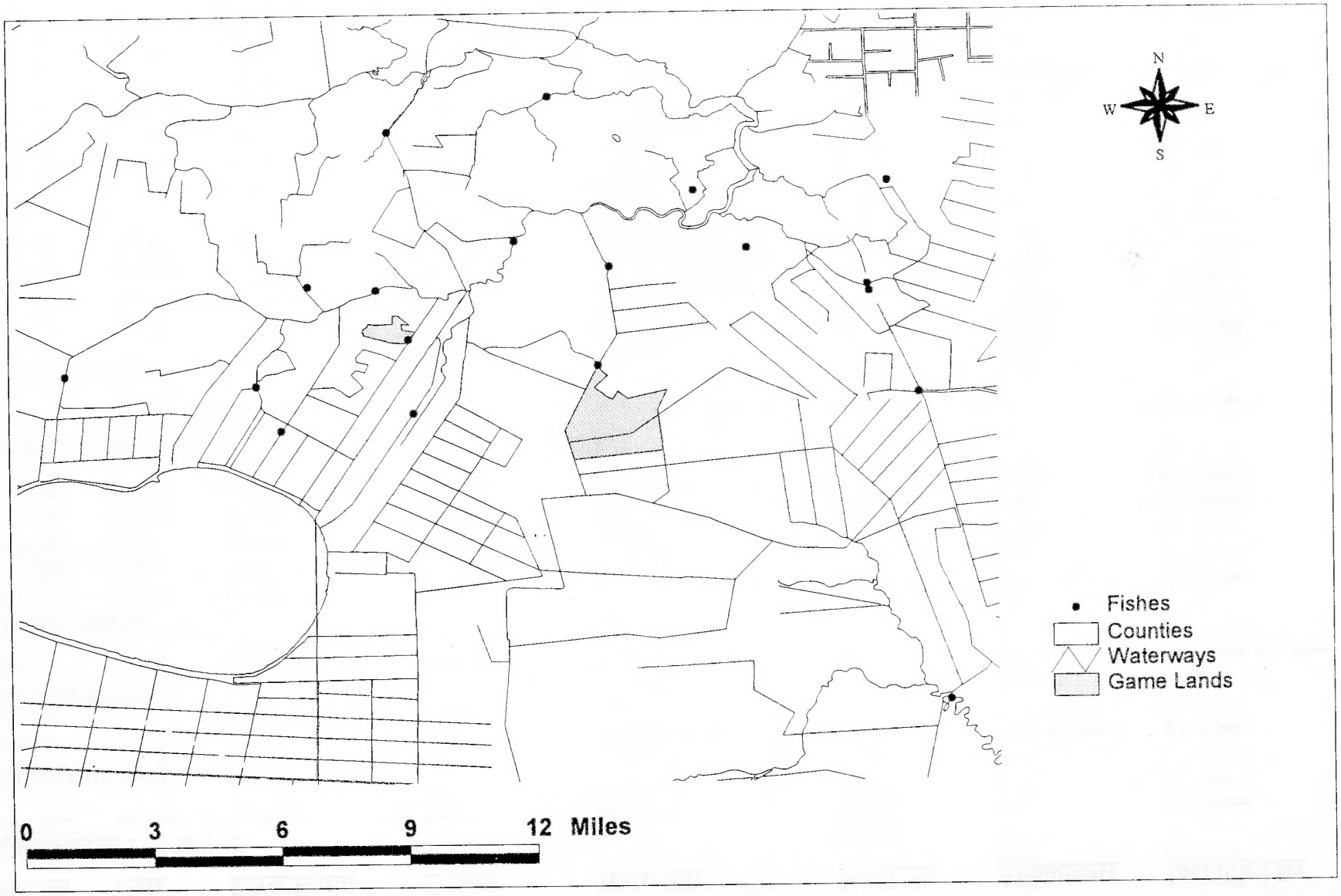

Figure 5b. Map of sites indicating where fishes were collected in the Lantern Acres Game Land aquatic inventory, Tyrrell and Washington counties, North Carolina, 2000.

Table 5c. Fish species found in Lantern Acres Game Land and associated waterways.

Anguillidae	
Anguilla rostrata	american eel
Amiidae	
Amia calva	bowfin
Aphredoderidae	
Aphredoderus sayanus	pirate perch
Catostomidae	
Erimyzon oblongus	creek chubsucker
Centrarchidae	
Centrarchus macropterus	flier
Enneacanthus gloriosus	bluespotted sunfish
Lepomis macrochirus	bluegill
Micropterus salmoides	largemouth bass
Clupeidae	
Dorosoma cepedianum	gizzard shad
Cyprinidae	
Hybognathus regius	eastern silvery minnow
Cyprinus carpio	common carp
Notemigonus crysoleucas	golden shiner
Esocidae	
Esox americanus	redfin pickerel
Ictaluridae	
Ameiurus natalis	yellow bullhead
Ameiurus nebulosus	brown bullhead
Noturus gyrinus	tadpole madtom
Percidae	
Etheostoma fusiforme	swamp darter
Etheostoma serrifer	sawcheek darter
Perca flavescens	yellow perch
Poeciliidae	
Gambusia holbrookii	eastern mosquitofish
Umbridae	
Umbra pygmaea	eastern mudminnow

Table 5d. Freshwater fish species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Ameiurus natalis							
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	rare	B.T. Watson
Ameiurus nebulosus							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	common	B.T. Watson, W.C. Starnes
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR1201(T)	rare	W.C. Starnes
000719.6btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1110	rare	B.T. Watson
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	rare	B.T. Watson
***Ameiurus* sp.**							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	present	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
Amia calva							
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	rare	B.T. Watson
Anguilla rostrata							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	rare	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	uncommon	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
Aphredoderus sayanus							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	uncommon	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	rare	B.T. Watson
000720.5btw	7/20/2000	Pasquotank	Tyrrell	Canal trib to Riders Creek	SR 1301 near SR1303	rare	B.T. Watson
Centrarchus macropterus							
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	rare	B.T. Watson

Table 5d (cont.). Freshwater fish species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Cyprinus carpio							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	rare	B.T. Watson, W.C. Starnes
Dorosoma cepedianum							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	uncommon	B.T. Watson, W.C. Starnes
Enneacanthus gloriosus							
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	rare	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	common	B.T. Watson
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	uncommon	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	uncommon	B.T. Watson
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	rare	B.T. Watson
Erimyzon oblongus							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	rare	B.T. Watson
Esox americanus							
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR 1201(T)	rare	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	common	B.T. Watson
Etheostoma fusiforme							
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	common	B.T. Watson
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	common	B.T. Watson
Etheostoma serrifer							
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson

Table 5d (cont.). Freshwater fish species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Gambusia holbrookii							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	abundant	B.T. Watson
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	common	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	common	B.T. Watson
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	rare	B.T. Watson
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	uncommon	B.T. Watson
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	common	B.T. Watson
000719.3btw	7/19/2000	Pasquotank	Washington	Scuppernong River	SR 1142	uncommon	B.T. Watson
000719.4btw	7/19/2000	Pasquotank	Washington/Tyrrell	Bunton Creek	SR 1308(W)/SR 1202(T)	uncommon	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	uncommon	B.T. Watson
000719.6btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1110	uncommon	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	uncommon	B.T. Watson
000719.8btw	7/19/2000	Pasquotank	Tyrrell	Roadside ditch	SR 1105 @ SR 1106	uncommon	B.T. Watson
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	common	B.T. Watson
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	common	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	common	B.T. Watson
000720.4btw	7/20/2000	Pasquotank	Tyrrell	Swampy trib near Second Creek	NC 94	common	B.T. Watson
000720.5btw	7/20/2000	Pasquotank	Tyrrell	Canal trib to Riders Creek	SR 1301 near SR 1303	uncommon	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	present	B.T. Watson
Hybognathus regius							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	rare	B.T. Watson
Lepomis macrochirus							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	uncommon	B.T. Watson
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	uncommon	B.T. Watson
000719.1btw	7/19/2000	Pasquotank	Washington	Thirtyfoot Canal	SR 1160 @ SR 1161	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	uncommon	B.T. Watson
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	common	B.T. Watson
000720.7btw	7/20/2000	Pasquotank	Tyrrell	Scuppernong River	SR 1105	rare	B.T. Watson
***Lepomis* sp.**							
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	rare	B.T. Watson

Table 5d (cont.). Freshwater fish species found in Lantern Acres Game Land and associated waterways. See text for common names.

Site No.	Date	River Basin	County	Waterway	Road No.	Abundance	Identified By
Micropterus salmoides							
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson
Notemigonus crysoleucas							
000718.2btw	7/18/2000	Pasquotank	Washington	Mountain Canal	SR 1156	common	B.T. Watson, W.C. Starnes
000718.3btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1163	rare	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	uncommon	B.T. Watson
Noturus gyrinus							
000718.4btw	7/18/2000	Pasquotank	Washington	Scuppernong River Canal	SR 1126-	rare	B.T. Watson
Perca flavescens							
000720.1btw	7/20/2000	Pasquotank	Tyrrell	Northwest Fork	NC 94	rare	B.T. Watson
000720.6btw	7/20/2000	Pasquotank	Tyrrell	Canal to Scuppernong River	SR 1105/SR 1108	rare	B.T. Watson
Umbra pygmaea							
000718.1btw	7/18/2000	Pasquotank	Washington	Trib to Scuppernong River	SR 1155-	uncommon	B.T. Watson
000719.2btw	7/19/2000	Pasquotank	Tyrrell	Bonarva Canal	SR 1118	patchy abundant	B.T. Watson
000719.5btw	7/19/2000	Pasquotank	Tyrrell	Trib to Scuppernong River @ Bull Bay	SR 1200+	rare	B.T. Watson
000719.7btw	7/19/2000	Pasquotank	Tyrrell	Canal @ game land	SR 1105	rare	B.T. Watson
000720.2btw	7/20/2000	Pasquotank	Tyrrell	Roadside ditch and canal	NC 94 @ SR 1307	uncommon	B.T. Watson
000720.3btw	7/20/2000	Pasquotank	Tyrrell	Trib to Second Creek	NC 94 near SR 1103	rare	B.T. Watson

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